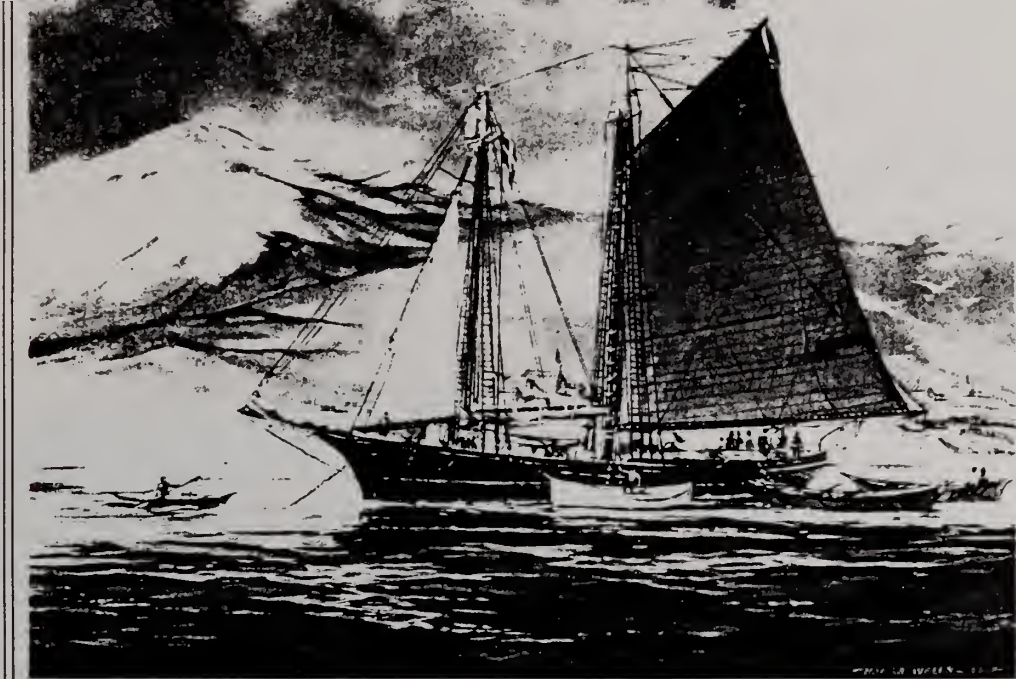


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The Waters of Boston Harbor and Massachusetts Bay



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An Expedition to the Water Planet

A Curriculum Guide for Schooner ERNESTINA's Underway Program

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An Expedition to the Water Planet:

Leaving a Wake

A Curriculum Guide for Schooner ERNESTINA's Underway Program

in the
Coastal Waters
of the
Commonwealth of Massachusetts

Including Activities, Contacts, Maps and Charts and Monitoring Programs

October 1996

by Alan Lee Hankin, Ph.D.

with
Tom Goux
Tora Johnson
Caitlin Schwarzman
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Funded by
Massachusetts Environmental Trust
Department of Education
Department of Environmental Management

Gregg Swanzey
Schooner Ernestina Director



The Commonwealth of Massachusetts

SCHOONER ERNESTINA COMMISSION



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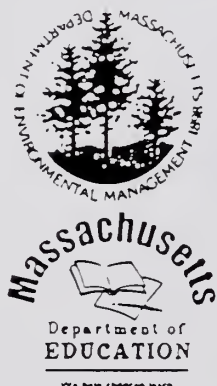
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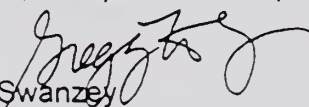


Thanks to primary funding from the Massachusetts Environmental Trust and the Department of Environmental Management and additional support from the Department of Education and New Bedford Public Schools, this guide is available for you in order to make the most of your expedition as you explore the marine environment aboard the Commonwealth's Tall Ship, the famous Schooner ERNESTINA ex Effie M. Morrissey.

You and your team will be stepping aboard a ship that has sailed Atlantic and Pacific waters and holds the record for furthest north of any sailing vessel. (80 degrees 22 minutes North!) You will depart from the dock and sail out onto waters that connect us to all parts of the globe. In order to prepare for the expedition, first work with your team to imagine what you might need to know on such an expedition of discovery, then do some research at the library, on the internet, or through local knowledge, etc.

At sea you will have a similar experience as the earliest explorers, the Whalers after the Great Sperm Whale, the biologists discovering yet unknown plant and animal species and cartographers charting new lands and the depths of the seas for the next voyagers to come. Put yourself in their place, ask the questions they might have and find out the answers!

Today our challenges are different than those one hundred years ago when ERNESTINA first started sailing. We know we must be stewards of our planet. We know that, in order to protect our oceans, we must preserve our wetlands and not pollute our watersheds. However, the spirit of the explorer is important as ever!



Gregg Swanzey
Director, Schooner Ernestina Commission

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An Expedition to the Water Planet

The Schooner ERNESTINA in the Biosphere: Leaving a Wake

Introduction to an Expedition

Join us on an expedition to the only planet known to be mostly covered by water, a planet where water controls weather and determines the cycles of life. Aboard the Schooner ERNESTINA we can investigate what makes this water planet work. Ernestina can take us not only from place to place, but to an era when wind and muscle were the energy and sail was the means for commerce, exploration, immigration and adventure. Through this lens of history we can begin to understand the forces, human and natural, that have shaped today's environment.

As we travel in the wake of the all those who have explored and exploited our Massachusetts shore, you'll ask the same questions asked by the earliest voyagers on our shores: What lives here? Why is it here? What does it need to live? How have these areas changed over time and what has caused these changes? These questions are of critical importance to our region's future. To understand our water planet means to understand what makes the oceans tick: temperatures, soundings (depth), life on the ocean floor, life in the skies over the ocean, sea life and the food webs which make up this complex environment.

Early settlers found a sea teeming with fish and shellfish, skies filled with birds too numerous to count, and clean rivers flowing into the sea. People needed these resources to prosper and saw no end to their use and replenishment. However, populations grew, especially on the coasts. Today, nearly 50% of the world's population lives in what is called the coastal zone (including the coasts of our oceans and great lakes), and coastal population is expected to double by early in the next century. We, the coastal dwellers, hold the future of our waters and coastlines.

Connections - History and Science

The Schooner ERNESTINA has a rich history of exploration. Beginning in 1926, Captain Robert Bartlett sailed to the Arctic, aboard the Schooner ERNESTINA (then called the EFFIE M. MORRISSEY). For the next 20 years he made annual voyages to the north, then regarded as the last frontier for adventure and scientific exploration. Museums, zoos and geographic societies funded his explorations and for them Captain "Bob" collected animals, mapped Baffin Island and other far northern regions and studied archaeological evidence of early native Americans, as well as contemporary Inuit. The scientists who traveled north with Bartlett pursued their own research interests: plankton studies, blood types and diets of Eskimos, mummies, plant life, and animal life.

The goals of our expeditions on board the Schooner ERNESTINA today and those of Bartlett in decades past are remarkably similar, though our motivations may be different. Bartlett and his scientific colleagues sought to explore, to chart, to touch the untouched and unknown reaches of our planet. Today we seek to understand our place in the cycles of the water planet. We are exploring how we have altered the balance with our eagerness to know and exploit.

The Schooner ERNESTINA was built in 1894, as a fast and efficient vessel for harvesting cod and haddock from the banks. She was part of a prosperous heyday in New England fisheries. Who knew, at the time, that the resources were so fragile? Overfishing has depleted stocks throughout the world (North Sea cod and haddock, 1930; Greenland cod, 1965; Georges Banks groundfish, 1990). New Englanders are now reeling under the ecological and economic consequences of years of overfishing.

Between 1948 and 1965, the ERNESTINA brought immigrants from the Cape Verde Islands to the shores of Massachusetts and Rhode Island where many looked to prosperous cities for employment in the fishing fleets, textile mills and agriculture. ERNESTINA was the last in a long line of countless sailing vessels bringing immigrants to Massachusetts shores starting with the Mayflower in 1620. As populations have grown and people have migrated from country to country seeking new

opportunities in coastal cities, the burden on our natural resources has overcome the Earth's ability to replenish itself.

Our relationship to the environment has changed over time and so have our values regarding use and exploitation of natural resources. When Bartholomew Gosnold explored Massachusetts' waters in 1602, the world appeared open for exploration and exploitation, huge, and unbounded. Resources were seemingly unlimited, inexhaustible. When Bartlett sailed, most of the world was mapped, airplanes and steamships had made the world smaller and human impacts were noted throughout the world. But, even though a few fisheries were already under stress, the seas and sustenance they provided was still considered unlimited and inexhaustible. Museums and zoos collected animals, without regard for rarity and little action was taken to control our impacts, especially on the coasts and seas.

Today, as in the past, what we do in our homes and business has a significant and visible impact on our waters. Run-off from our roads, our lawns and our homes carries the wastes from our cars, fertilizers, septic systems, farms and pets. Our industries, long the culprits in environmental contamination, are less often the causes of significant contamination today, but created pollution problems in our waters and sediments which will last for many generations. Waste water treatment plants, though improved, contribute to the nutrients and bacteria which plague our waters.

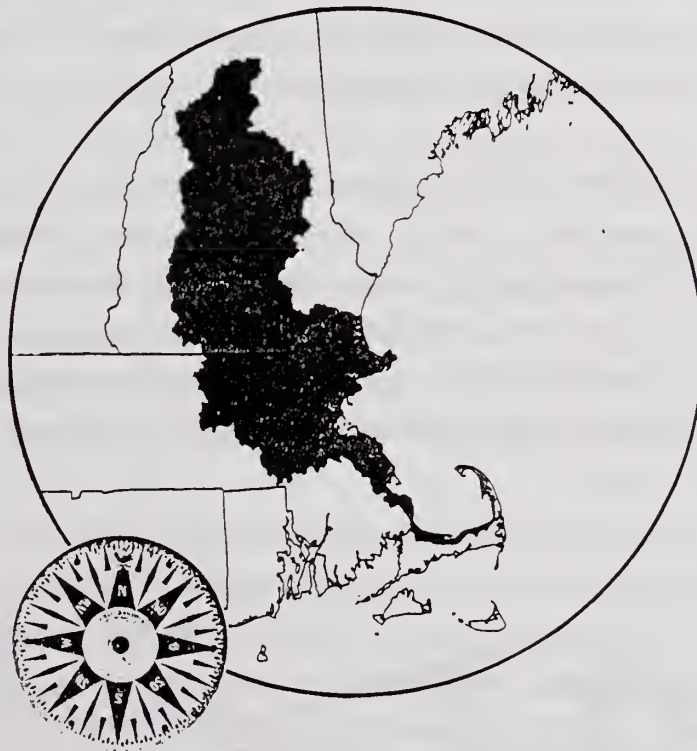
In the last few years, research programs have clarified the problems which we confront. Modern day expeditions to Planet Earth include those sponsored by the National Aeronautic and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA) and other people and organizations. However, we still have much to learn.

Your expedition is a part of these efforts. We will pose questions just as Bartlett and his crew of scientists did in the Arctic. We will pose questions just as the people working today to understand the coast and oceans have asked. From the Schooner ERNESTINA, we will be able to take samples, make collections and analyze the data collected.

But we are not alone in this expedition. Many groups and individuals are also working to understand our coastal and oceanic problems better. These groups will be our partners along the way, sharing information we gather. Whether sampling Cape Cod Bay or Mt. Hope Bay, we will be in touch with those folks to find out if our efforts to prevent pollution, or reverse its effects are working. Together, we can make informed decision about the future of our waters.

Just as the young men who accompanied Bartlett found the ship and sea a challenge, so too will we be challenged in our expedition on the Schooner ERNESTINA. Physical, intellectual and social challenges will confront us as we design and implement our research and as we work as a team to learn, explore and enjoy the worlds of ship and sea.

Welcome aboard our expedition to the water planet, where we share the Planet Earth with its living things. Let us tread so lightly as to leave nothing more than our wake on the sea's surface.

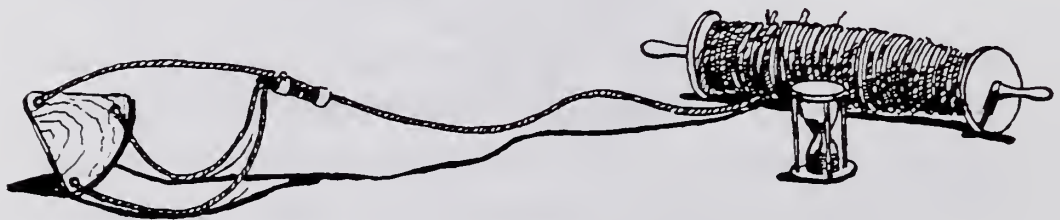


Connections: The State Frameworks for Science and Technology and Mathematics

The Massachusetts Common Core of learning is the foundation for education reform in Massachusetts. Paired with the seven curriculum frameworks (science and technology, mathematics, art, English, language arts, social studies and world languages) the core provides the basis for educational program development and assessment. The Science and Technology and Mathematics frameworks are the guidelines and guideposts which provide direction and milestones for the Expedition to the Water Planet.

Scientists, as the Frameworks state, “own questions”, that is they pursue answers to questions which they formulate, care about and have the curiosity to pursue. “Owning the questions” is based on having specific habits of mind which set the intellectual stage for learning in a program such as the Expedition. Seekers of knowledge are curious and open minded but also skeptical (from the Frameworks). Generating and respecting evidence, having the persistence to find out the answers to questions, determining what questions follow from the answers and performing the experimentation which gives valid and reliable information, are all parts of the frameworks and the appropriate habits of mind of the scientist/student.

Critical to the expedition is the development of a sense of stewardship and caring. Being a part of a ship, while participating in the studies of the coastal and oceanic environments, develops stewardship for the vessel and for the waters it sails and the coasts it visits. Caring comes from knowing. As has oft been stated, we care most about those things we know best. We act most for those things we know and care about most.



The expedition addresses each of the Frameworks components: inquiry, each of the domains of science (physical sciences, life sciences and earth/space sciences), the use and applications of technology and the importance of science and technology in human affairs (see details in each section and activity) . As stated in the October 1995 Draft of the Frameworks the expedition will:

- involve the discovery of the fundamental relationships in the natural world by asking questions such about observations, nature and “what if?” propositions.
- include the appropriate use of tools that increase our ability to make observations through the use of technology and to ask questions about how do things work, how can we get things done and how can we make them work better.
- apply the knowledge gained and create more questions to be answered as the results of the observations and the answers to the questions relate to what we each do in our daily lives - the implications of our actions and what we can do about the impacts we have which cause people to suffer, or to benefit - how do we increase the benefits without increasing the suffering?

The Waters of Massachusetts

The Massachusetts coast is 1,800 - 2,000 miles long (depending how you measure it) and meanders around islands large and small, along beaches, salt marshes, rocky shores, and, in contrast, past heavily developed urban centers and sparsely developed residential communities. Major cities, such as Boston, New Bedford and Fall River, have used the waters of this coast as a place to dump wastes while at the same time extracting power, fish and shellfish from these same waters. Many Massachusetts cities have based their economies in part on what they could extract from the sea: the fish from the Grand and Georges Banks and the whales found as far away as the Pacific.

Coastal areas have long been treated as cheap, convenient disposal sites for industrial and municipal wastes. These wastes include sewage (human wastes) and other wastes from our homes, petroleum products, sediments, and industrial wastes (among them organic compounds and heavy metals). For many years thousands of acres of coastal waters were unsafe for shellfishing and swimming due to elevated levels of bacteria. Coastal ecosystems have been changing due to excessive

quantities of nutrients, specifically nitrogen compounds, entering into bays and harbors and accelerating a process known as eutrophication. In recent years increased awareness of public health and ecological impacts of coastal pollution have lead to stricter enforcement of regulations by federal (Environmental Protection Agency - EPA), state (Department of Environmental Protection - DEP), and local agencies (including boards of health and conservation commissions). Citizen efforts, including water quality monitoring and public participation in planning and decision making, are helping to keep cleanup and pollution prevention on target. Our coastal waters are becoming cleaner.

However, decades of abuse cannot be remedied overnight. Many industrial pollutants, such as PCB's, heavy metals, TCE, and Dioxins persist for many years in the environment and are difficult to clean up.

Sewage treatment plants are far more effective than they were 20 years ago, but problems with design and capacity continue to allow some sewage to be released into our waterways. Polluted run-off continues to plague are coastal waters. The debates over who is responsible for past and present pollution problems and who should pay for our previous mistakes will be a matter of debate for many years to come.

Connections - People, Behaviors and the Sea

Our coastal waters do not stand alone, for every coastal city sits on a river, and every river in eastern Massachusetts ends in the sea. Each river is vulnerable to problems of polluted run-off from a wide array of sources. Every municipality and small community, indeed every square mile of our state, is in the watershed of a river or sits on an aquifer which flows to rivers and the sea. Water flows through and past our homes, businesses and recreation areas in its endless cycle, and we can affect it at any point along its journey. For one example, when farm run-off enters the Westport River, it's not only Westport's problem; it's a problem for all of us who live downstream and depend on clean rivers and seas. The run-off is a problem for shellfishermen, swimmers, boaters, property owners and wildlife. For a second example, an aquifer of groundwater on Cape Cod was contaminated with jet fuel from Otis Air Force base and that water is flowing through the ground to the

ocean, passing under and through the communities of Mashpee and Falmouth on the way. These communities, formerly reliant on groundwater, must find other, uncontaminated sources for the water they use for drinking and washing.

Each of us plays an important part in the contamination of our coastal waters. Run-off from our roads can contain pet and other animal waste, fertilizers from our lawns, oil and other petroleum products from our cars, and hazardous substances, such as pesticides or cleaners, that we do not dispose of properly. All of this waste eventually makes it to our streets and shores. People contribute to the problems of the marine environment daily, often without realizing it.

For example, the finger is often pointed at cities, large industry and big oil for the major problems such as bacterial contamination, toxics pollution, and oil spills, such as the Exxon Valdez spill in Alaska. In fact, what we as individuals contribute makes up much of the bulk of the contamination. Faulty septic systems contribute bacteria and nitrogen to coastal waters. Household hazardous wastes contribute to the toxics in our waters and each year, boaters along our shores contribute more oil from small leaks and spillage than the massive oil spills. The impacts from the big sources, although initially deadly to the wildlife and ecology of these areas, does lessen over time. Our small contributions often continue.

The coasts weren't always seen this way. The coast of Massachusetts, long a destination for summer vacations and even longer a source of bountiful fish and shellfish stocks, was once thought of as inexhaustible. Boston dumped its waste, including human wastes, right into Boston Harbor. New Bedford and Fall River did the same with their local waterways, the Acushnet and Taunton Rivers.

But the culprit wasn't only the big cities. The small towns of Cape Cod, Cape Ann, and Buzzards Bay, all saw the coastal waters as a resource and a dump. By the 1930's the situation was so bad that some local waterways were closed to shellfishing for the first time. People got sick from eating animals, apparently healthy on the outside, that were contaminated inside. The contamination, more often than not, was

pathogenic (disease causing) bacteria from human wastes dumped into coastal waters, leaching from septic systems, pumped out from boats or piped to harbors from sewage treatment plants.

Less obvious than shellfish contamination, which makes you sick quickly and is therefore easily detectable, are the heavy metals (copper, nickel, zinc, chromium) and organic substances (PCB's - polychlorinated bi-phenols, other PAH's - polycyclic aromatic hydrocarbons, and petroleum products) which are harder to detect and whose impact is often insidious. To understand these substances you need to know their distribution and fate in the marine environment: in the sediments, the water column or the organisms. The greatest concentrations of heavy metals is in the sediments and the animals that inhabit that zone, especially around docks in harbors and areas where boats are moored.

Clearly, there are many sources of contamination which have changed the waters and coastal environments of Massachusetts. The three main priority pollution problems and impacts are:

- impacts from sewage (pathogens and fecal coliform) contamination on human health,
- excessive nitrogen or nutrients entering the bays and estuaries from run-off and the resultant degradation of water quality and loss of habitat, and
- the impacts of contamination due to toxic substances on fish, lobster and shellfish and the impacts on human health and the environment.

Connections - Monitoring the Coastal zone

Efforts are underway to clean up the large sources of sewage by constructing new waste water treatment facilities in cities, such as Boston and New Bedford. The same effort is underway on a smaller scale in coastal municipalities and private homes (through Title V as the septic clean up regulations are called). Efforts are underway to better understand and keep track of the sources of contamination and to fix what can be fixed as quickly as possible.

Monitoring is underway to see if these efforts to improve Massachusetts' coastal waters are working. Monitoring is on-going

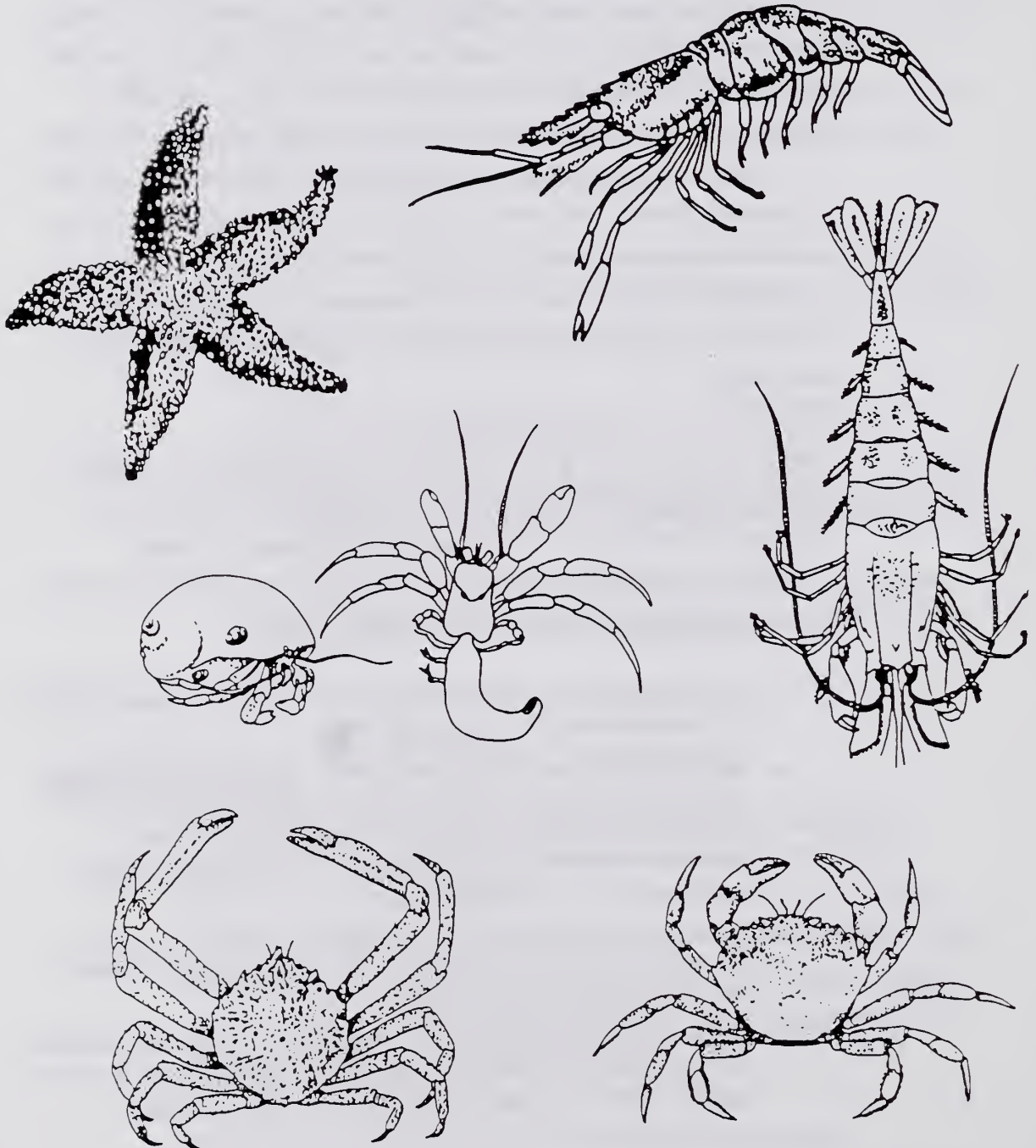
sampling which scientists and citizens do to determine if there are changes in the biology, chemistry or physical aspects of an ecosystem. Monitoring answers questions such as what are the sources of pollution and physical changes in the bays, what are the effects of these changes and, if we begin acting to stop pollution, are our efforts working?

Water quality monitoring is performed by the EPA, the National Marine Fisheries Service, the State DEP, Division of Marine Fisheries, local resource managers, such as shellfish officers, by schools and colleges, and increasingly by private citizens as part of efforts by environmental groups to promote local action and public awareness. Samples are taken at the same locations and conditions at the time of the sampling are noted (time of day, tides, water temperature, weather and any other important site data) many times over weeks, months or years. Some samples may be processed on site (as with test kits) while others are processed back at a laboratory (often a state run lab, a state certified private lab or a school or college which works cooperatively with the monitors).

Sampling allows us to gather information on pathogenic and fecal coliform bacteria, nitrogen and nutrient levels, and toxics in the environment. In addition, the data collected provides a clearer understanding of the ecology of the area where the samples are being taken. Monitoring studies include collecting data on:

- **physical characteristics of the water:** water temperature, clarity or transparency, color, currents, depth;
- **chemical characteristics of the water:** salinity, pH, dissolved oxygen (a measure of water quality by determining how much oxygen is available for living things), nutrients (nitrogen), presence of petroleum products and oil slicks, heavy metals, organics (PAH's and PCB's);
- **biological characteristics of the water:** distribution, number, condition and kinds of plankton, fish, shellfish, birds, marine mammals, algae and sea grasses.
- **human impacts:** presence and distribution of petroleum products and oil slicks, solid wastes, outfall pipes, algal blooms, diseases and tumors on fish, fish kills, pathogens (fecal coliform).

On our expedition to the water planet on board the Schooner ERNESTINA we will be doing water quality monitoring similar to that done by the federal, state, and local officials and by citizen monitoring groups. You will also receive the actual information which these groups are collecting, sail to the same sites, do your studies and then compare your information with that being collected separately. Your expedition data will be compiled and sent to those agencies and scientists who will then be able to use your information to indicate if, when and how more studies need to be done.



An Expedition to the Water Planet

The Schooner ERNESTINA in the Biosphere: Leaving a Wake

An Expedition to Boston and Massachusetts Bay

Our expedition to New Bedford and Buzzards Bay will begin in the City of Boston and will take us out past the most active Harbor in New England, past the Deer Island Waste Water Treatment facility, past the more than 15 “Harbor Islands” and onto the waters of Massachusetts Bay. Named for the Native Americans who inhabited this region, Massachusetts Bay includes all the coastal communities south of Gloucester and Cape Ann and north of Plymouth, plus their offshore waters out to and including Stellwagen Bank. The Bay itself, therefore, is a semi-sheltered region of the North Atlantic Ocean.

Our expedition to Boston and Massachusetts Bay will draw on the history, the ecology and the problems confronting this region. The activities from which we will choose allow us to answer many questions about Boston and Massachusetts Bay. Among the many questions we may ask are:

- what are the characteristics of this region which give Boston and Massachusetts Bay its unique mix of marine and other animals?
- what are the natural forces which shape the Harbor and Bay today?
- what are the human actions which create the environmental problems around the Harbor and Bay?
- what and who lives in the watershed of the Bay and in why are they there?

- what do humans value about this region, what do they need, what do they want?

During the last ice age, known to geologists as the Wisconsin Stage of the Pleistocene Epoch, a massive ice sheet covered all of Canada and substantial portions of the northern United States. This ice reached thicknesses as much as two miles, depressing the land beneath its enormous weight. In our area this ice sheet reached its southernmost limit at Cape Cod and the Elizabeth Islands. However, because so much of the world's fresh water was locked up in ice, sea level was far lower than it is today and the coast was far to the east of its present location. Around 16,000 years ago, climatic changes began to melt the ice sheet. This led to two major changes - a rise in sea level as more and more ice melted and a rise in the land as it "sprang back" after being relieved of the weight of the ice. Although these two changes tended to counteract each other, they happened at different rates, so that the actual coastline "seesawed" back and forth reaching something approximating its present configuration only about 3,000 years ago.

Early Expeditions

Our expedition will be one in a long line of explorations to the region. The first explorers were the Native Americans who came to this area not far behind the retreating ice sheets. There is evidence that Native Americans had reached the Boston Harbor area 10,000 years ago, and a spear point found on Long Island In Boston Harbor has been dated at 9,000 years old. These early Native Americans moved from place to place through the year to take advantage of seasonal abundance. In spring they caught alewives as they returned to fresh water rivers and streams to spawn. In summer they built fish weirs to catch larger fish, and also gathered shellfish. Middens, piles of spent clam and oyster shells, have been found in many locations along the shores where settlements were located. The Bay region abounded with birds (including the now extinct Great Auk), fish, shellfish (such as lobsters, clams, scallops, oysters, crabs, and mussels) and even

marine mammals were known to frequent the area. Tribes moved inland in fall, gathering wild rice along those rivers where it occurred. Hunting was a year-round activity, but especially in winter. In many areas of Southern New England tribes “managed” game by setting periodic fires to clear the undergrowth in forests. This practice not only improved the quantity and quality of browse available to wildlife, it also made hunting (and travel) much easier.

Around 1,000 years ago these patterns began to include agriculture. Crops including corn, beans, squash and tobacco had originally been domesticated in Mexico. Both the crops themselves and the techniques for growing them spread gradually north then east through North America. In our region, agriculture was practiced as far north as the Saco River in Maine. Native Americans often cleared small sections of forest for their crops. But occasionally clearings were much larger. Francis Higginson, writing in 1630, described a hill near Boston from which one could see “thousands of acres” with “not a tree in the same.”

Many European explorers “discovered” Boston Harbor. Among them, according to legend, was Leif Ericson, a Norseman, who is thought to have sailed these waters as early as 1003 A.D. The Cabots, English explorers in the 1400’s, may have viewed the Harbor. Records point to either Bartholomew Gosnold, in 1602, or Sieur De Monts, in 1604, as the first to explore the Harbor. The first permanent European settlement, by the Pilgrims in Plymouth in 1620 was followed in rapid succession by settling of many other communities around the Harbor and Bay and in the watershed: Boston, 1630; Cambridge, 1636; Braintree, 1640; Beverly, 1668. Boston proper was settled by William Blaxton, a clergyman who moved to Beacon Hill in 1625 to be joined by other Puritans in 1630. By 1633 several thousand colonists inhabited twelve towns located around Massachusetts Bay. The principal occupations, in addition to agriculture was in shipyards, gristmills, and fisheries. By 1640, the number had risen to 18,000, in 30 towns, as compared to only 3,000 people in the nine towns of Plymouth.

Boston itself appeared far different on maps of the time than it does today. At the time of the colonists Boston was a small peninsula of only 783 acres connected by a thin strip of land to the rest of the mainland. Present day Charles Street was the location of a beach where Sam Adams and others swam in what is now the Boston Public Gardens, but which in the 1700's was the open waters of the Back Bay.

The downtown and residential areas of Boston were connected to the sea through a series of wharves, Long Wharf being the largest, extending nearly 5 modern city blocks from the Harbor to the dry upland. Long Wharf today, in comparison, is less than two blocks long and most of what was the original Wharf is covered by State Street. Back Bay, along the Charles River, was a swampy area, decried in the summer for its mosquitoes and the odor of the wastes of the City which were dumped there. The hills of Boston, such as Beacon Hill, were prized residential areas, but steep sided, and began to be leveled in the 1700's, the materials removed being used to fill in the Back Bay, South Bay and other coastal areas of the city. By 1930 the land area of Boston proper was 1,800 acres and the gradual absorption of the suburbs brought the city's area by that date to 47.8 miles.

Boston Harbor Islands

The Boston Harbor Islands also went through rapid changes over those years. Long used by the Native Americans to fish, plant crops and trade with other tribes, the islands were also more comfortable than the mainland in summer, thanks to cooling sea breezes. English settlers used the islands as a source of wood, cutting down nearly all the trees and then grazing sheep and cattle on the cleared land. The wood was used for shipbuilding and firewood. Thompson Island was used as an Native American trading post, Deer Island for hunting, Slate Island as a source of slate for home building in Boston. By the 1700's the islands were a resort destination with guest houses on Brewsters, Long and Peddocks Islands (some of which had gambling and boxing matches).

In the 1800's islands became convenient places for hospitals, prisons, poorhouses and reformatories, including a prison for Confederate soldiers at Fort Warren on Georges Island. Long strong points for Boston Harbor defense, the islands saw forts or other military construction beginning prior to the War of 1812 (Fort Independence on Castle Island - the oldest continuously used fortification in the United States, Fort Warren in the Civil War (Georges Island) and many smaller facilities built as shore watch stations during World Wars I and II.

The physical shapes of the Islands have changed as well. Castle, Long and Deer Islands were connected to the mainland via causeways. Spectacle Island grew as it was increasingly used as a dump, first for the waste from the city and surrounding communities and then as a disposal site for the wastes from the Boston Central Artery/Third Harbor Tunnel project. By the 1950's, trash had increased the size of Spectacle Island by 59 acres and its height by 100 feet!

Boston Harbor is divided into segments. The inner Harbor, into which the Mystic and Charles Rivers empty, is surrounded by downtown Boston, Charlestown, South and East Boston. Logan Airport to the north and Castle Island to the south delineate the inner Harbor's mouth. Dorchester Bay, south and east of the inner Harbor and into which the Neponset River flows, includes Thompson Island, Spectacle Island, Moon Island and Long Island (the last two connected to the mainland by causeways). The outer Harbor includes Green Island, Little Calf Island, Calf Island, the Little, Great, Middle and Outer Brewster Islands and Shag Rocks (formerly more of an island but disappearing from erosion). Most of these islands are also homes to nesting colonies of seabirds, particularly herring and great black backed gulls and increasingly cormorants and shorebirds. Graves Light, the outermost light in the Harbor is located on rocks in this region known as Graves Ledge. The nine islands of Quincy Bay include Hangman Island, Raccoon Island, Grape Island, Nut Island (attached to the mainland and home of a waste water treatment plant), Peddocks

Island, Rainsford Island, Georges Island (home to Fort Warren) and Gallops and Lovell's Island.

Ecology of Boston Harbor

Boston Harbor was formed nearly 15,000 years ago, when glaciers receded leaving deposits of glacial till and debris behind, forming the Harbor islands on the east and south and a shoreline of inlets, estuaries and bays to the west. The islands and peninsulas protect the Harbor from the effects of the open ocean but tidal currents and winds still shape the Harbor and the Harbor's environment. Currents, wind, and the inflow of freshwater effect the primary characteristics of Harbor waters: how the waters move (circulation); how salty the waters are (salinity) and the temperature of the waters. Nearly 500,000,000 gallons of freshwater flow into the Harbor each day from the Charles, Mystic and Neponset Rivers. The drainage basin, of nearly 500 square miles, is inhabited by more than 2,000,000 people, most of whom receive their freshwater for drinking from Quabbin Reservoir, in central Massachusetts, and dispose of their wastes through the systems of the Massachusetts Water Resources Authority and the Deer Island Waste Water Treatment Facility. Until recently (1991) sewage sludge was dumped into the Harbor. At present, nearly 450,000,000 gallons of treated waste water enter from the Treatment Facility each day, an amount of fresh water almost equal to that of all the daily river flow. Studies of water flow in the Harbor have shown that sea water does enter between the islands with each tidal change but the rate of turnover is only one third to one fifth the water in the Harbor.

The Harbor and Islands are home to a rich variety of bird life including summer breeders, seasonal migrants and winter residents. In the summer gulls, terns, shorebirds (including the endangered piping plover), long legged waders (black crowned night herons and great blue herons), ducks, and many species of perching birds (such as sparrows, wrens, swallows, warblers and thrushes) call the Harbor home. During the migration, large flocks of geese, especially Canada geese and brants, ducks, shorebirds

from Canada, hawks and perching birds pass through the Harbor and islands. The winter residents are many and varied including snowy owls, feeding on small mammals at Logan Airport and large rafts of sea ducks including eiders, scoters, buffleheads, oldsquaw and goldeneye. Year round, the endangered peregrine falcon, one pair of which nest in downtown Boston, can be seen flying from the city to the Airport to feed on shorebirds or migrants. These birds, established through the efforts of the Massachusetts Natural Heritage and Endangered Species Program, breed on the towers of the city on ledges far above the streets.

The waters of Boston Harbor abound with fish and shellfish, harvest for thousands of years until areas became contaminated from the actions on the land. Small baitfish, including mummichogs, killifish, and silversides can be found in the shallows and marshes. Cod, of great importance to the region's fisheries for hundreds of years, has been credited as a foundation of the New England economy, as demonstrated by the "sacred cod" gold codfish on the Massachusetts State House. Striped bass was an important commercial fish until its decline in the 1980's but remains an important recreational fishery. Flounder (both yellowtail and winter) wait for small fish on the bottom of the Harbor, exposing themselves to the pollutants in Harbor sediments and become an indicator of environmental quality. Mackerel, in large colorful schools, vary from highly abundant to scarcity due to their means of reproduction; releasing eggs wherever the fish may be during breeding.

Shellfish, including lobsters, clams (hard and soft shelled), blue mussels, and several species of crabs inhabit the Harbor, with an active lobster fishery in those areas opened to the fishery. Lobster traps can be seen throughout the outer Harbor area. Previously, lobsters were found with a high level of black gill and shell diseases, both of which are receding thanks to the efforts to clean up the Harbor.

Marine mammals frequent the Harbor throughout the year. Harbor porpoise, the smallest of the cetaceans and never seen in large

numbers in the Harbor, are seen with increased frequency even within the inner Harbor. Harbor seals are seen in large numbers throughout the Harbor. In winter and spring, more northern species of seals, such as harp and hooded seals, are beginning to be seen. At times even the large gray seal, which breeds as far south as the islands between Nantucket and Martha's Vineyard, are seen. The reason for the increase in number and diversity of marine mammals is that the protections afforded these animals by the Marine Mammal Protection Act (1973) has allowed populations to increase rapidly on the breeding grounds.

Vegetation, both subsurface and attached, is found throughout the waters of the Harbor. Rock weeds (algae) and kelp, line the shores and islands. Formerly, eel grass was abundant on the bottoms of the Harbor in shallow regions. Now nearly extirpated due to disease and pollution, eel grass is being transplanted to the Harbor to help restore the natural ecology of the region. Irish moss, important in making agar and in the production of ice cream, is found in deeper waters but washes up onto beaches after storms.

Pollution and Boston Harbor

Most people are aware of the environmental problems of Boston Harbor, a harbor once declared by President George Bush as the most polluted in the country. In part, he was correct at the time (1988). The problems stem from urban and industrial life. Sanitary (human) wastes flowed into the harbor in storm drains, closing beaches to swimming and areas to shellfishing and lobstering, closures which continue in some areas to this day. After a single rain episode, as many as more than 50 pipes carried waste water (until the 1990's), especially road run-off and some sanitary wastes, (human wastes), into the Harbor adding to the bacterial (pathogen contamination) and nitrogen (nutrient) problems. But the problems weren't just from the 2,000,000 people who live on or around the Harbor and its watershed. More than 5,000 industries are located in the watershed of the Harbor

and the wastes from industry wound up in the Harbor and circulated throughout the region as well.

The Harbor has the distinction as having some of the most contaminated sediments in the world as a result of centuries of dumping and run-off. The major contaminants are the organic substances, PCB's, which were used by industry for many years as an insulating "oil" in electrical and other equipment. Found to cause cancer (carcinogenic) and possibly miscarriages (in addition to some evidence that they impact reproductive hormones in male animals), PCB's were banned for use in this country in the 1970's but they persist in the Harbor's sediments in excess of the allowable or safe amounts.

Boston Harbor generates \$1.22 billion dollars annually from its role as a shipping port (as of 1991) and provides work to nearly 9,000 workers, who receive a payroll of \$187 million dollars. To ensure that the flow of ships into and out of the Harbor is unimpeded, the Harbor must be periodically dredged. The real issue is what to do with the contaminated sediments from this harbor. Found in the sediments are heavy metals, which add to the overall contamination of the benthic environment. Some of these metals, such as copper, have a detrimental effect on the growth eelgrass, a very important flowering plant which grows under estuary waters and is home to young fish and scallops while at the same time providing food for migratory and overwintering waterfowl. Heavy metal contamination of the sediments prevents or retards the growth of this plant species. These heavy metals also have a detrimental effect on human health, particularly when the metals bioaccumulate, that is concentrate in the tissues of animals, such as flounder and lobsters which spend much time on the ocean floor.

The wastes from the watersheds, some carried by the rivers, others carried by pipes to the waste water treatment plant, all found their way into the Harbor. From 1919 until 1984, the Metropolitan District Commission (MDC) was responsible for sewage and water systems in Boston. In 1984, thanks in part to a law suit filed by the

City of Quincy, a new agency the Massachusetts Water Resources Authority (MWRA) was formed, charged with coming up with a plan to prevent additional wastes from entering the Harbor. Studies of Boston Harbor or surveys along its shores, both found significant problems. Oxygen levels, measured as dissolved oxygen in water, were so low as to prevent the use of the Harbor by many fish and shellfish. Too many nutrients had entered the Harbor, stimulated an excess production of algae, the algae would die and decompose. The decomposition process robbed the Harbor of its oxygen. Shoreline surveys even found human wastes washed up on beaches.

The most ambitious harbor cleanup ever undertaken began at that time. The MWRA developed a plan which controlled street run-off and the flow from pipes directly into the Harbor. Most significantly, however, was the plan, now come to fruition, to upgrade the primary waste water treatment facility on Deer Island to a state of the art secondary treatment facility and to cease all dumping in the Harbor. The first step in this \$8 billion project was to control run-off, except after severe rain episodes. This step has been completed and now beaches around Boston Harbor are open and safe for the public most of the summer. The next step was to stop dumping sludge, the solid waste matter which is strained out of the waste water, into the Harbor. As of 1991 no solid sludge is being dumped. Instead this nutrient rich material is taken to a pelletizing plant in Quincy where it is heated to very high temperatures to kill viruses and bacteria and then turned into an effective organic fertilizer. The step still underway, and coming on line each year, is for the Deer Island Facility to use secondary treatment, a process which removes 85% of all suspended solids from the waste water and 85% of the nutrients in the waste water which cause oxygen to be consumed in the Harbor.

These steps have had a significant impact on the quality of Boston Harbor waters. The waters are visibly clearer and, significantly, the levels of dissolved oxygen have risen to the point where the Harbor can be compared to the cleaner open ocean waters outside of the Harbor.

The last step in the process will be to pipe the treated waste water through a tremendous pipe to an area 9.5 miles out to sea in Massachusetts Bay, where the waste water from Boston and the 42 communities will be diffused into the marine environment through 420 perforated pipes. The impacts on Massachusetts Bay have been carefully studied, with monitoring work to follow.

Ecology of Massachusetts Bay

“Massachusetts Bay” is a somewhat vague term, since there is no clear division between the Bay, the Gulf of Maine to the North (and of which Massachusetts Bay is a part), or Cape Cod Bay to the south. We will consider Massachusetts Bay to include all the coastal communities south of Gloucester and Cape Ann and north of Plymouth, plus their offshore waters out to and including Stellwagen Bank. The Bay itself is a semi-sheltered region of the North Atlantic Ocean. Currents within the Bay tend to circulate counter-clockwise, so that currents along the shore flow from north to south. This same counter-clockwise circulation is found in both the Gulf of Maine and Cape Cod Bay. Water enters Massachusetts Bay from a variety of sources - from the open ocean to the east, from a branch which breaks off from the Gulf of Maine current and flows around Cape Ann and into the Bay and from runoff from the land.

The watershed which feeds the Bay covers about 1,500 square miles not including the watershed of the Merrimack River, which, although it doesn't enter directly into the Bay, does account for the greatest single source of fresh water entering the Bay. Other larger rivers enter the Bay are, from north to south, the Danvers, the Mystic, the Charles, the Neponset, Weymouth Fore River, Weymouth Back River, the North River and the South River. Waters in the Bay flow in turn into Cape Cod Bay, where they follow the inside curve of the Cape's “arm” and then flow around Race Point and out along the back of the Cape. Tides along the Bay's shore range from 8 - 10 feet. Water depths within the Bay range up to 200 feet, except for Stellwagen Bank, which lies 80

feet of less beneath the surface. Stellwagen Bank is a plateau comprised of sand and gravel rising above the continental shelf. Like Georges Bank and a number of banks off the Maritime Provinces of Canada, Stellwagen is a nutrient-rich area extremely important to fish, sea birds and Marine Mammals. Stellwagen Bank was designated a National Marine Sanctuary in 1992.

The shoreline of Massachusetts Bay is more than 270 miles long and consists primarily of sandy beaches and salt marshes, along with extensive tidal and mud flats.

Habitats and Wildlife of Massachusetts Bay

Long known for its commercial and recreational fisheries (flounder, scup, striped bass, bluefish; lobsters, clams, oysters, scallops) Massachusetts Bay is a region of bountiful resources, increasing population and the impacts from the interaction of these two factors.

Around the bay can be found many critically important wildlife habitats. Approximately 8,400 acres of salt marshes ring the Bay. **Salt marshes** are critical habitat to wildlife in the region and to fisheries both in the region and further to sea. Salt marshes are composed of a variety of unique grasses which capture nutrients from the sea and from fresh water rivers draining the uplands. The combination of location and the ability to thrive in this interface of land and sea are important characteristics of salt marshes. Of equal, if not greater importance, is the amount of organic material which salt marshes represent. An acre of salt marsh is more productive than any other biological system, including agricultural acres, on Earth. This productivity, in the form of plant growth, then becomes the basis for the food web in the estuary and sea. The salt marsh grasses decompose and release their nutrients for small animals, such as crabs, snails, and tiny shrimp to eat. These animals and other organisms of the salt marsh become the foundation on which a food web is built which extends to approximately 70% of all the fish and shellfish we consume each year.

Salt marshes were once thought of as stinky, muddy, unpleasant wastelands, ripe for destruction as cities and communities extended to and along the shore. Salt marshes were filled in to create more dry land, used as waste dumps for industrial wastes, have had railroad tracks placed on their waters edge, preventing regular exchange of water and nutrients and as a result, have been lost or become other habitats. Estimates now show that nearly 50% of this critical habitat has been lost in Massachusetts and elsewhere, a possible cause for the decline of fisheries stocks. In some locales salt marshes shifted to *Phragmites* (pampas grass) brackish water marshes, with much lower productivity, due to construction of an elevated railroad bed which cut off the marsh from the sea. Wetlands protection in Massachusetts and beyond have saved these areas from future destruction. In some locations the salt marshes weren't filled in directly.

Eelgrass beds, found in sandy or muddy bottoms, can be found in areas where sunlight penetrates to the Bay floor, generally in areas up to 20 feet deep. Scallops and the young of several species of fish require time in eelgrass beds to grow and develop. Several bird species, such as brants, a small goose, thrive on eelgrass in the winter and declined partially in reaction to declines of eelgrass beds in the past 60 years. Nearly destroyed by a "wasting disease" during 1931-32, eelgrass has recovered only to be threatened again by disease and by the ravages of human actions. These actions, including the addition of excess nitrogen from non-point sources, has lead to the growth of algae on eelgrass and to the blooms of free floating (planktonic) algae above eelgrass beds. The combination of these threats and the fact that eelgrass cannot grow on sediments contaminated with some heavy metals (as in our harbors) has lead to eelgrass loss as a major environmental concern for the region. Resource managers and people dependent on the fisheries of the Bay monitor eelgrass beds as an indicator of environmental quality.

Other Massachusetts Bay habitats include **barrier beaches** (1,800 acres) and over 11,000 acres of **tidal flats**. The beaches are

critical habitat for endangered and threatened bird species, such as piping plovers and least terns, both of which nest on beaches. Beaches also serve as buffers against storms, absorbing the shock of the waves and abnormally high tides which accompany these episodes.

Beach use is a study in conflict. Both wildlife and people want to be there at the same time: in the summer. Beach management is also a study in management success: careful management around piping plover nests on beaches lead to a remarkably rapid recovery of this species from a low of only 790 nests along the Atlantic seaboard in the mid 1980's (approx. 135 in Mass.) to nearly 1250 nests total and 441 nests in Massachusetts.

Tidal flats, often overlooked in our understanding of the coasts are found along our shores either within estuaries or exposed to the sea. Although people know them as good shellfishing grounds, they also play important roles as a buffer to storm waves and as a source of sand for beaches. Many species of worms and other invertebrates call tidal flats home.

When taken together with the open waters and benthos, the Bay supports fisheries of lobster, shellfish and finfish.

The fish populations of Massachusetts Bay are renowned and have played an important role in both the culture and economy of the region for 400 years. According to studies done in 1990, the value of fish and shellfish landed in 1990 was \$53 million (including Cape Cod Bay). Lobsters were 60% of this total and finfish were 33%. There were an estimated 634,000 recreational fisherman. Overfishing has lead to the categorization of 8 out of 18 species of finfish as being overexploited. Only 15% of the total finfish landed in 1970 are landed today. Haddock has virtually disappeared. Blue fin tuna, a species is very high demand in Japan, can grow to 1,000 pounds or more, and draw sport and commercial fishers to the area. When caught they are valued at \$35 per pound or more, are shipped to Japanese markets overnight and can bring \$350 per pound retail the next day. As a result, the population of adult tuna

in Massachusetts Bay and other areas is thought to have declined by 90% in recent years.

Other important finfish resources include flounder, bluefish, striped bass, mackerel and cod. These resources have been under pressures from overfishing, loss and decline of spawning areas and, some scientists hypothesize, declining water quality and environmental contamination. Whatever the cause, there has been a shift in the finfish populations throughout New England waters. Where flounder, cod, haddock and halibut may have abounded in the past, skates and spiny dogfish now make up much of the biomass. This shift has led to a change in the fisheries and the target species for commercial fishing.

Shellfish, including lobsters, clams (hard and soft shelled), ocean scallops, blue mussels, and several species of crabs inhabit the bay, with an active lobster fishery in those areas opened to the fishery. Ocean scallops and lobsters are considered overexploited. Lobster traps can be seen throughout the Bay. Many shellfish beds, measured in the thousands of acres, are closed to shellfishing due to high levels of bacterial contamination. Nearly annual blooms of red-tide, caused by dinoflagellates in the water, can lead to some shellfish concentrating toxins in their tissues, ultimately causing paralytic shellfish poisoning in people who eat those mussels or clams.

Massachusetts Bay is home to a rich diversity of animal life, some species of which concentrate in this area in greater numbers than anywhere else on the Atlantic seaboard. Concentration areas are Stellwagen Bank, home to several species of marine mammals. Whale watches to Stellwagen Bank began in 1976 and, thanks to the efforts of the Center for Coastal Studies in Provincetown, the New England Aquarium and others, constitutes one of the most studied communities of marine mammals anywhere. Seen on the Bank are humpbacked whales, fin whales, minke whales, sei whales, a rare blue whale, the precariously endangered north Atlantic right whale, pilot whales, Atlantic white-sided dolphins and, rarely, orcas, and bottle nosed dolphins. Harbor seals and other,

more northern seals can occasionally be seen on the Bank, also. Approximately 1,250,000 people per year go on whale watches to these areas .

Stellwagen Bank is not the only place where marine mammals can be seen in the region. Harbor seals become especially common during the winter months when they can be seen hauled out on beaches and rocks which emerge at low tide. With greater frequency each year, harbor seal and other seal species pups are found along the shores of Massachusetts Bay. Many are thought to be stranded, but in reality are awaiting the return of their mothers, who are feeding. Some are stranded and these animals are often taken to the New England Aquarium for rehabilitation and eventual release.

As with Boston Harbor, Massachusetts Bay, with its rich nutrient base and water circulation patterns is home to a variety of bird life including summer breeders, seasonal migrants and winter residents. The same species seen in the Harbor can be seen around the Bay, especially in the small embayments and sheltered areas. During migrations, however, large numbers of pelagic or open ocean species can be observed on Stellwagen Bank, including shearwaters, storm petrels, gannets and an occasional fulmar. Large rafts of ducks, especially scoters, oldsquaws, and mergansers and smaller groups of alcids (such as puffins and murre) can be observed. The winter residents are many and varied including eiders, scoters, buffleheads, oldsquaw and goldeneye.

The combined areas of Massachusetts and Cape Cod Bays have 34,000 acres of saltmarshes, one of the world's most productive ecosystems. Many of these marshes are remnants of larger marshes destroyed as cities and towns spread along the shore. There are nearly 15,000 acres of tidal flats in the Bay region. Eel grass is found in the subtidal regions, where light can reach the benthic or bottom of the Bay, but estimates have not been put forth as to the total acreage of this critical habitat. From Nahant north,

rocky shores are common coastal features, with their populations of rock weeds, barnacles, blue mussels and periwinkles.

Pollution and Massachusetts Bay

Massachusetts Bay receives the wastes and other impacts of human activity from the nearly 3,000,000 people who live around the Bay. Water flows from the 1,500 square miles of watersheds, on the many rivers which enter the Bay and from the large number of boats, both recreational and commercial, which use the Bay daily. The principal sources of contamination are the watersheds of Boston, parts of the North Shore and the Merrimack River, whose waters flow around Cape Ann and into Massachusetts Bay. Other culprits include waste water treatment facilities which contribute heavy metals especially copper, lead and zinc. Industries discharge their wastes, not directly into the waters but into the waste water treatment facilities.

In Massachusetts Bay and Cape Cod Bay nearly 80,000 acres of shellfish beds are closed, mostly due to bacterial contamination as measured by coliform. These beds are closed to prevent human health problems such as gastroenteritis, an inflammation of the digestive system, with symptoms similar to the flu. Hepatitis A also occurs as a result of eating contaminated shellfish. In a study done between 1961 and 1984, 6,000 people had contracted gastroenteritis and 1,400 contracted hepatitis but many cases are unreported because people misdiagnose what ails them.

When concentrations of bacteria, specifically the indicator species fecal coliform, exceed 14 colonies in 100 milliliters of water shellfish beds are closed to prevent disease. When the number exceeds 200 colonies per 100 ml, swimming beaches are closed.

The principal culprits in contributing bacterial contamination to nearshore waters are faulty or inadequate sewage treatment plants and systems, storm drains, stormwater runoff, cattle and horse farms, pets and wild animals. All warm blooded animals have the

bacteria in their systems and therefore can produce indications of contamination, even if the contamination is not from human wastes.

Monitoring and Clean Up of Boston Harbor and Massachusetts Bay

Modern day “expeditions” to Boston Harbor and Massachusetts Bay are concerned with the water quality and the effects that pollution and human actions have on the natural resources of the area.

To understand the ecology of the region meant to first develop a baseline of information and then to monitor changes over time. Many organizations and institutions, including the Massachusetts Water Resources Authority, Woods Hole Oceanographic Institution, the University of Massachusetts Boston, the New England Aquarium and state and local agencies have been working to understand what is happening to the Harbor, Bay and the small embayments (harbors and estuaries) which surround the open waters. Coordination of this effort began in 1985 as part of a national effort to understand our coastal waters. A leader in the citizen involvement work is Save the Harbor/Save the Bay, a not-for-profit coastal advocacy organization. Long term monitoring by the MWRA and others will help determine if efforts to improve the Bay are effective.

This program of monitoring work presently underway, is coordinated along with the efforts of the Massachusetts Bays Project, the a National Estuary Project (begun in 1990) of the EPA to prepare and have adopted a Comprehensive Conservation and Management Plan. Research efforts and data collection by the Project created the first bay-wide understanding of the water quality problems (pathogens, toxics, nutrient enrichment) of the Bay. With the adoption of the CCMP, due in 1996, efforts to clean up and protect the Bay are underway, many at the local, town level. But progress is notable, as areas such as Boston Harbor where dissolved oxygen levels are rising and in some small embayments, where careful control of sewage and other wastes are leading to

reopened shellfish bed. Most dramatic, however, are the number of beaches which the public can enjoy, beaches closed for many years due to contamination of local waters.

Our expedition will work to understand the complex ecological and social systems which are Boston Harbor and Massachusetts Bay and will build on the work of these many concerned and committed people and organizations.

Activities For An Expedition on the ~~Schooner Ernestina~~ Instructions for use:

The questions which scientists ask about the marine environment focus on one or more of four areas: the physical parameters, the chemical parameters, biological parameters or human impacts. The expedition to New Bedford and Buzzards Bay will have the opportunity to touch upon each of these areas or to delve into one of the areas in depth. Classroom activities in advance of the expedition will make this expedition more productive. Suggested pre-voyage activities are included below. (e.g. videos, classroom hands-on experiences, problem solving and simulation gaming)

The expedition will collect data which others may not be studying at the present time (such as shoreline use), while monitoring environmental parameters which others are studying. Maps (charts) are provided to locate existing monitoring sites to which the Schooner ERNESTINA can make sail and explore. To monitor an area means to go back to specific sites and make the same tests using the same procedures, accurately record data and then share findings.

The following pages describe the activities relating to an expedition to New Bedford and Buzzards Bay. They are organized in the following manner:

1. a list of the sampling or study activities with the key piece of equipment necessary for each test, recommended general locations for performing those tests and an estimated time on task analysis for each activity
2. detailed curricula and descriptions of each activity for studying the physical, chemical, biological and social characteristic of the region
3. charts and tables to assist with the program implementation
4. recommended assessment methodology for the students and for the program
5. names, addresses, phone numbers and other pertinent data regarding agencies who are working on water related issues in the region and have recent water quality data or similar

information which can be useful for the expedition. They are noted as to whether they can provide "instant" access to information or periodic reports. They are also annotated as to whether they are interested and can use information gathered on the expedition.

Note: the sediments of Boston, in some locations are severely contaminated and should be handled very carefully if at all - disposal of samples becomes a major problem.



To use these curriculum materials, the instructor should determine the goals of the expedition. If the goal of a particular voyage is to study the social dimensions of our relationship to the environment, i.e. human impacts, then more activities from that section can be structured to take place in 2 - 3 activity locations on deck.

Any mixing and matching can be done to modify the program to the school's objectives, the voyage objectives, the interests of the instructors or the age of the students on board. All tasks are designed for small groups (2 - 3 students) working in a larger group of 9 - 12 students with the groups rotating on a 20 - 30 minute basis from station to station. At each station, the small groups will have time to perform between 1 - 5 tasks (activities), often working independently and then sharing the information they have collected at the end of the voyage.

Single task stations create a difficulty in supplies and equipment - the number of test kits or nets, for example, is limited. Therefore, if a single, long term task is being performed at a station, the instructor should have 2 - 3 students perform that task while others are performing shorter tasks in the same general area.

Instruction sheets (laminated) and data sheets (for each group) will assist the instructor in "delegating" or assigning tasks to the small groups. For longer voyages, beyond 3 hours, all of the tasks can be accomplished, based on objectives of the expedition and duration of voyage.

Of special value is to perform the same tasks in various areas, times of day, by different groups of students and under various conditions, so as to then determine patterns, trends, and variability in sampling and analysis. Some of the tasks require "below decks" analysis, specifically the **plankton** study and identification which will require microscopes (dissecting or student scopes) and keys to the **plankton** or field guides. Field guides will also be necessary for any macroinvertebrate identification and for fish and marine mammal identification (on longer expeditions). These should be part of a library on board. Also part of the library and on board equipment should be videos and a small monitor set-up. These can be especially handy as advanced organizers, as summaries of findings, as enrichments or as useful instructional tools when weather or other conditions prevent sampling.

Each activity has specific instructions on its use and the connections between the activity, Massachusetts Education Reform (Curriculum Frameworks), other activities and studies on-going in the region studied. Each task has the following sections:

Expedition Task - name of the activity.

Purpose - why is this task important and what are we trying to find out by performing the task.

Objectives - what are the specific outcomes which we will be able to observe as a result of performing the task.

Skill Development - what specific behaviors, manipulations, tool use or similar skills to we expect students will develop as a result of performing this task.

Materials - what are the consumables and equipment which we will need to perform this task.

Getting Started - what "hook" or question/action can the instructor take to involve the students in the activity right away.

Procedures - what are the steps necessary to complete the task - at times these may refer to other tasks which are part of the overall procedure (use of a collecting bottle to acquire samples for salinity testing, for example).

Station Logistics and Safety - where on board should this task take place and what are the dangers and risks which should be addressed with the students and carefully monitored by the instructor.

Findings and Observations - what did you discover by performing the task and what do you record (and how) after completing the task (data sheet where needed).

Discussion Questions - what are the series of questions which come to mind as a result of performing the task - the first question is general, asking students to look at the "big picture" initially and then other questions focus more on specifics.

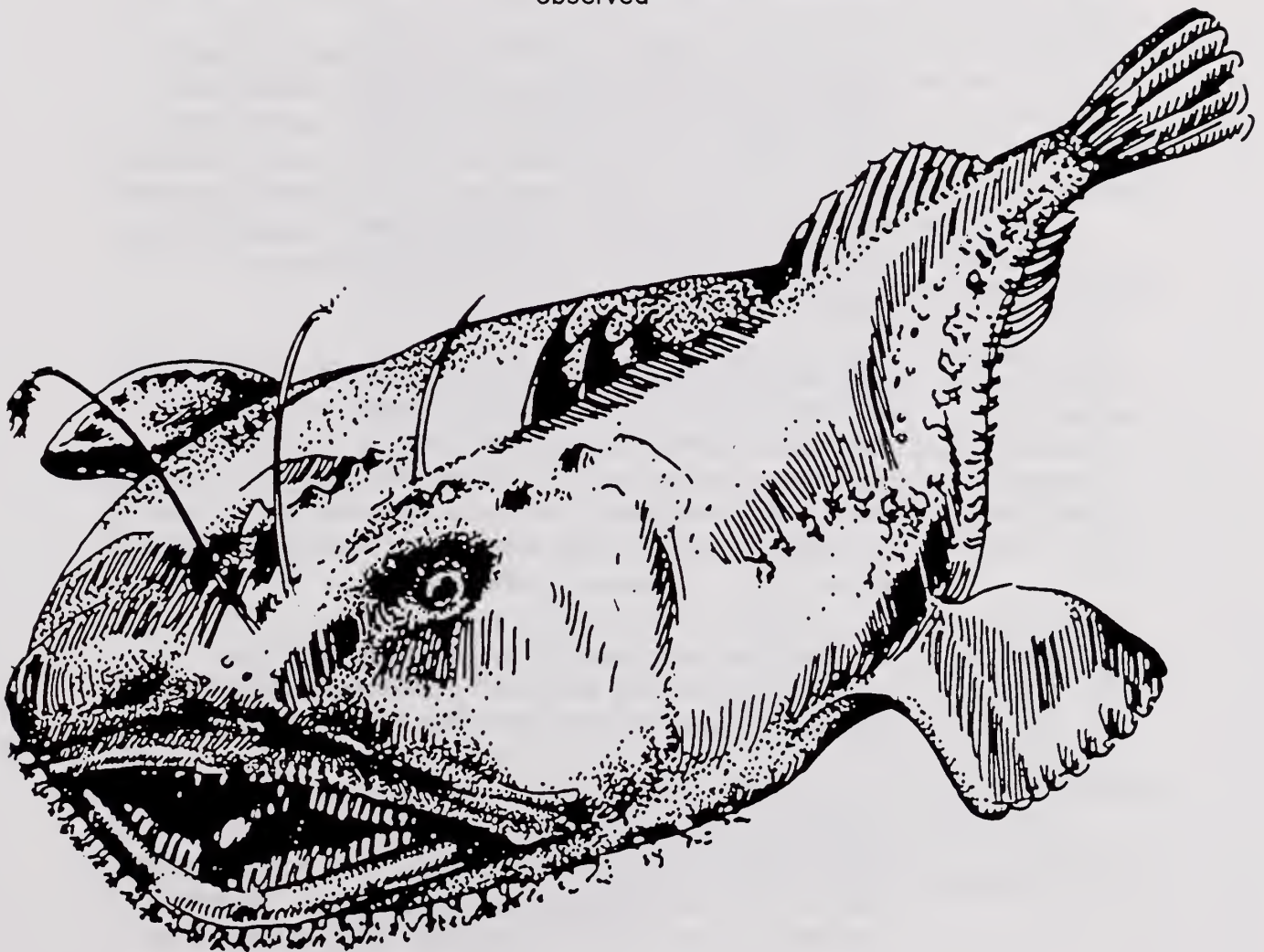
Estimated Time on Task - how long should this task take (a range is given based on age, repeated sampling and other variables).

Connections - what does the data collected by this activity mean and how is it related to studies elsewhere by scientists and others concerned about the marine and coastal environment.

Links to Other Activities - what other activities in this curriculum (and elsewhere) relate to this task and how can you compare findings from different methods which explore similar questions or collect similar data.

Links to Curriculum Frameworks - what are the key aspects in the Massachusetts Curriculum Frameworks for Science and Technology and Mathematics which this task addresses.

Application of Frameworks - what are the specific connections between the activity and the Massachusetts Curriculum Frameworks for Science and Technology and Mathematics which can be demonstrated and observed



General Instructions ~ An Inquiry Approach to Science, Technology and Mathematics Education

Each generation apparently needs to discover for itself that learning is what children and adults do, and that teaching is designed to facilitate the learning process not to fill an empty mind with information. For the past 40 years science educators in this country and elsewhere have known this fact and have attempted to employ ever improving methods to facilitate learning in children. What we know and knew is that science is a process of discovery and inquiry learned best by discovery and inquiry. In spite of this fact, teachers have continued to present science as a body of knowledge rather than as a way to understand and make sense of the natural world. Unfortunately, in many freshman high school science courses, students will be asked to memorize more new vocabulary words than they will be asked to learn in freshman Spanish (for example): nearly 2,000 new terms.

We have also learned over the past 40 years that each person brings to the learning environment sets of pre-conceptions, often misconceptions about how the world works. The learning process that we go through therefore is a series of challenges or additions to these conceptions of the world from which we construct a new understanding of how the world works. The approach is called the constructivist theory.

The fact that we all view and learn to understand the world differently has also been clearly presented in learning research. Some of us learn better by doing, others by seeing, and still others by hearing. We also know that each of us brings a slightly different "intelligence" to the learning process, some of us as logical thinkers, others as intelligent in music or art, or interpersonal skills.

On the Schooner ERNESTINA we recognize these advances in learning and have incorporated them into the process of learning on board and in our curriculum.

Students should be asked, in advance of any task, what they know already about what they are going to be testing. This advance work allows the instructor to have a better sense of the pre- (or mis-)conceptions of the students. Students should be asked to predict what they will find when they perform the task, not told in advance what to expect. Let them discover how the world works for themselves and they will construct a better interpretation, we hope, than they had when they got started. These first questions can be in the

form of a “hook” or activity which is a means for grabbing the students.

1. Students should be helped, but not lead, through each of the tasks. Instruction cards, drawings, or demonstrations will give them enough information by which to use the tools or technologies with which we will equipment them to study the world. Most of the equipment is simple, safe and has limited range of potential harm to the student, the environment or the boat.
2. Students will use their strengths best by working in small teams. Larger groups will not allow for each student to participate; individuals may not feel as comfortable or competent with individual aspects of the tasks. The instructors will therefore need to direct small group activities in each of the stations on board and to rotate students from task to task as time allows. Don't expect to have every student do everything. Except on long voyages, that is an unattainable goal.
3. Lectures and orientations should be brief, focused and recognize the attention span problems of the audience who is on a boat, which is exciting enough in itself, and which rocks, rolls, and is located in a harbor or on the water where few of the students regularly go. Active involvement of students will lead to active learning. Lectures and talks can be very effective in the right setting, but learning does not always follow from such instruction.
4. Wrap ups on programs are often of short duration, ask the simple questions first, and the integrating questions last, if at all. Reviewing data on board and going over each small groups findings can be unproductive given the excitement and schedules of students who have just spent 1 1/2 hours on a boat or 3 or more hours at sea. Focusing on the integrating questions first may seem hard, and is with younger students, but it allows for a single concept to be reinforced rather than the individual data to be covered. Wrap ups per group per station is recommended and wrap up at the end of the voyage should be of a general nature, addressing the relationship between the voyage as a whole and the Schooner ERNESTINA and each student's role in the biosphere.
5. Life is a buffet from which we make choices and so is science, technology and mathematics education aboard the Schooner ERNESTINA. Each voyage will provide the opportunity to collect data, analyze results and have fun while learning. No two voyages may be exactly the same. The tasks may be different, course may vary, and instructors will vary. The tasks performed, however, will allow each student to become a part of the expedition to planet earth, collecting her/his own data to add to the collections of others and to build her/his understanding of science and technology.

HAVE FUN!

Activity Table ~ Part One

Parameters	Equipment/Materials	Observations	Time	Sampling Location
Air/Water/Motion (pick four or all)	thermometers	air temperature	5 to 10	sample from ship or dock
	hygrometer	<u>relative humidity</u>	5	sample from ship or dock
	compass/chart	course and heading	10	sample from ship on station/moving
	cloud charts	cloud cover and type	5	sample from ship or dock
	sounding lines/inclinometer	<u>depths/soundings</u>	10	sample from ship or dock
	anemometer	wind speed	5	sample from ship or dock
Water Chemistry (pick 4 plus DO kit)				
	<u>dissolved oxygen</u> kit	<u>dissolved oxygen</u>	20	sample from ship or dock
	<u>dissolved oxygen</u> probe	d.o.	5	sample from ship or dock
	salinity test kit	salinity	5	sample from ship or dock
	pH papers	pH	5	sample from ship or dock
	pH test kit	pH	5	sample from ship or dock
	nitrogen test kit	total nitrogen	15	sample from ship or dock
	recording sheets	petroleum evidence in water	5	sample from ship or dock
	Van Dorn bottles	stratification of data		sample from ship or dock
Physical Parameters/Water (pick four)	thermometer (multiprobe?)	water temperature	5	sample from ship or dock
	Forel Ule scale	color	5 to 10	sample from ship or dock
	Secchi Disk	transparency	5 to 10	sample from ship or dock
	Membrane Filters	<u>turbidity/suspended sediments</u>	10	sample from ship or dock
	drogue	<u>currents</u>	10	sample from ship on station/moving
	graduated hand lines	wave height	5	sample from ship or dock
	compass	wave direction	5	sample from ship on station/moving
	hydrometer	density	10 to 20	sample from ship or dock

Activity Table ~ Part Two

Layers in water - <u>abiotic</u>	see above	see above				
	gravity corer		<u>benthic sediments</u>		10 to 15	do not sample inner harbor - in Bay only
Layers in water - <u>biotic</u>	plankton tows (various mesh)		neuston/phyto/zooplankton		15 to 25	sample from ship on station
(pick one)	binoculars		bird life/marine mammals		10	sample from ship or dock
	Pomar grab		benthic organisms		15 to 25	do not sample inner harbor - in Bay only
	gravity corer		benthic organisms		10 to 15	do not sample inner harbor - in Bay only
	scallop dredge		fish and macroinvertebrates		15 to 25	do not sample inner harbor - in Bay only
	mini-trawl		fish and macroinvertebrates		na	sample from ship on station/moving
	minnow trap		small fish, macroinvertebrates		na	sample from ship or dock
	crab trap		macroinvertebrates		na	sample from ship or dock
	multiplate sampler		fouling		10 to 15	sample from dock
Human Impacts	binoculars/recording maps		shoreline mapping		10 to 20	sample from ship or dock
(pick two, maximum)	nautical chart		anoxic zone mapping		10 to 15	sample from ship on station/moving
	sanitary survey maps		point and <u>non-point</u> sources		10 to 15	sample from ship moving near shore
	eel grass bed/metals maps		benthic contamination		10 to 15	sample from ship moving near shore
	Millipore apparatus or test kits		<u>bacterial</u> contamination		20 to 25	sample from ship or dock
	binoculars/recording sheets		floating debris			
					20 to 25	sample from ship moving near shore

Samples from the Deep (Collecting Bottles)

Purpose -The surface of the ocean may as well be a solid wall in northern waters. Being able to see clearly to depths below just a few feet is unlikely due to algae, **sediments** and other contributors to **turbidity**. The same situation applies to the physical and chemical factors which make up our sea. To best understand the true complexion of these waters requires collecting samples from below the water surface.

With animals, this process can be accomplished with traps, often baited, to attract and hold the animals until they are brought to the surface. The problem with water is that any which we attempt to bring up in an open container will mix with the water it passes through on the way up.

By collecting at depth we get a better image of the complexity and rich variety of zones and life in the sea. Collecting bottles have been designed to allow us to collect a sample and prevent it from being contaminated as we return that sample to the surface.

Key Points -

- technology lets us explore areas we cannot get to otherwise
- collecting bottles allow us to sample from various depths giving us a glimpse of what is below the ship
- technology does not have to be complex to be effective

Objectives -To use a collecting bottle to bring water samples to the ship from depth.

Skill Development - Use of water collecting bottle, measurement and tracking of samples

Materials -collecting bottle weighted line messenger

Station Logistics and Safety - Three students can work together on this task and then should rotate so that each gets an opportunity to collect and send the messenger. Care should be taken in lowering the collecting bottle over the side so as not to fall overboard nor to scrape the hull with the bottle or messenger. Use of the collecting bottle is relatively simple and is designed for collecting water for other studies on deck or at the dock.

Getting Started - Set up the scenario that the students need to find out something about what is going on deep below the ship. To get there they will need to swim (in simulation), which means holding their breath as they dive. Ask students in your group to hold their breaths for as long as possible - time them. Compare their times to a sperm whale which can hold its breath for nearly an hour and can dive a mile - how far do they think they could get on one breath in order to bring something back to the surface.

Procedures

1. Tie the weighted line (unweighted end) securely to a cleat on the boat.
2. The bottle will have both ends open and will require these ends to be latched so they do not close on the way to the depth for the sampling. Pull on each end cap until it latches open. Attach the bottle securely to the line.
3. With one student holding the bottle away from the hull, carefully lower the bottle and line into the water never letting go of the line. Watch the graduations on the line until the depth from which the sample is to be taken is reached. Stop the line at this point.
4. After making sure the line is securely attached at the point where you stopped its descent, attach the messenger to the line and drop the messenger down the line to close the bottle.
5. Haul the bottle up to the surface. The top of the bottle can be opened to pour a sample of the water collected into a container for the testing to be done. Do not test samples within the collecting bottle itself.
6. The same procedure should be repeated as many times as is needed for the tasks requiring water from depth.

Findings and Observations - See each task requiring water at depth (density, dissolved oxygen, nitrogen, temperature, color, salinity).

Discussion Questions -

1. Why is sampling at depth important to a complete understanding of how the seas work?
2. Why is technology important for our complete understanding of the processes of the natural world?

Connections - Researchers need to know more than what they can find out by observing the sea from its surface. Many of the advances in the last 25 years has been in our ability to understand what happens at depths far below the surface. Using radar, sonar, remotely operated vehicles (ROV's such as Jason), miniature submarines (such as Alvin) and deep

water divers have opened up much of this world to us. Before all of these techniques became available to scientists, however, collecting bottles were developed that allow us to take water and other samples at depth. Nets, traps, corers and bottom grabs allowed us to better understand the life in the depths, but each has its limitations and is selective in what they catch.

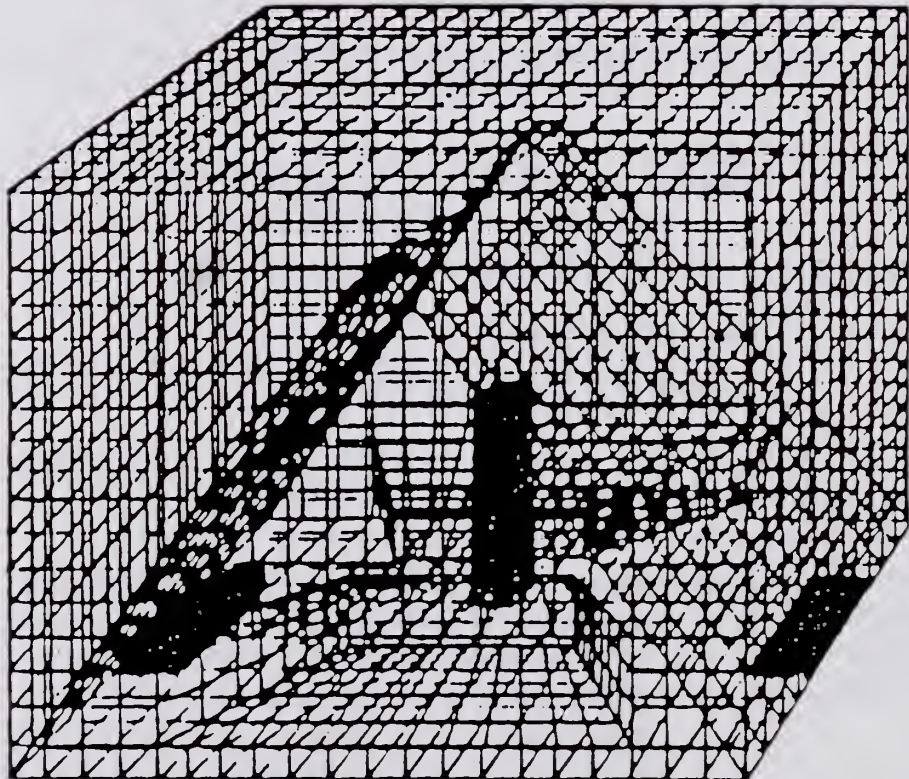
In Buzzards Bay and vicinity you will be sampling from as little as 20 feet or as much as 200 feet of water. The data you collect after you test your samples will help to describe the ecology of the Bay.

Links to Other Activities - See each task requiring water at depth (density, dissolved oxygen, nitrogen, temperature, color, salinity).

Estimated Time on Task - 5 - 10 minutes depending on number of samples and age of group.

Links to Curriculum Frameworks - See each task requiring water at depth.

Application of Frameworks -The use of technology to expand on human senses is an important component of science education. This task is designed as development of the ability to use such a tool.



Density and Destiny - Salt in Water

Purpose -By understanding the density of water we are able to make connections between physical parameters (temperature and salinity) and the distribution of living things. Most living things live in a narrow range of temperatures and salinities. Very few organisms can move from areas of high salinity to an area of low salinity and visa versa. Salmon and eels are two examples.

Water at 4°C has a mass of 1 gram per cubic centimeter (also called a milliliter). Water becomes more dense at lower temperatures or if there are substances with a higher density, such as salts, dissolved in it. What makes water unique is when you reach 39°F (10°C) water begins to become less dense until it freezes. This fact is very important because if solid water didn't become a ice at a lower density than liquid water, it wouldn't float and the ecology of the Earth would be very different from what we know.

Key Points -

- cold water is denser than warm water
- salt water is denser than fresh water
- salt and temperature work together to determine the density of sea water versus fresh water
- the deeper you go, the colder and more dense the water - this fact is called a temperature gradient

Objectives - To determine the density of water at various depths and locations throughout the expedition. To understand the concept of density and how density plays a role in the destiny of water in the marine environment.

Skill Development - Use of Hanson Bottle to collect water and hydrometer to analyze density.

Materials

- Hanson or other collecting bottle for collecting at depth.
- Hydrometer - a weighted glass float with a scale which floats higher in denser water and is easy to use.
- Clear beaker or other clear deep but narrow container
- Can of Diet Pepsi
- Can of Pepsi

Station Logistics and Safety - Three students can work together on this task and then should rotate so that three recordings of data are made. Care should be taken in lowering the collecting bottle over the side so as not to fall overboard nor to scrape the hull with the bottle. Use of the collecting bottle is relatively simple but **care must be taken in the handling of the hydrometer (it is made out of glass) and the reading of the data.**

Getting Started -Float a can of Pepsi and Diet Pepsi in a bucket of water. Ask the students why they think one floats and the other does not. Ask them how they would float in the ocean versus a lake or fresh water river. Ask them if they know why.

Procedures (This task can be done on any side of the ship by a team of three students.)

1. Each student should take a turn collecting a sample, testing the sample for density with the hydrometer, measuring the sample's temperature and recording the data. Follow the instructions for use of a collecting bottle (see Water Samples from the Deep). Different bottles have different ways for closing when the depth you want to sample is reached. At least three samples should be taken; one each at the surface, at midwater and near the bottom.
2. The hydrometer should be carefully removed from its storage sleeve and gently placed on the bottom of the clear narrow container. For this task we will use a graduated cylinder made out of plastic. The water sample should be carefully poured into the cylinder until the hydrometer floats freely. Hydrometers come with stems which are marked with densities. Carefully read the density from the scale - it will be a number slightly above 1 (one) and will have decimal points to note.
3. Record the density of the water, the depth from which it was taken and any other pertinent observations (location for instance) on the data sheet. Each student should perform this task for one of the depths.

Findings and Observations -Record the location, temperature and density of the water. Data can be recorded in a variety of manners based on the type of cruise or program. Vertical data (density at depths) gives a two dimensional image of density distribution. Densities can also be taken over the length of a voyage or at specific targeted locations during the voyage. The data collected can be graphed using either a combination of depth vs. density, location vs. density or, using a computer which is capable of displaying three dimensions, location vs. density vs. depth, a true transect of the waters through which the vessel travels. Conversion tables (see attached) can be used to determine salinity directly from water density and temperature.

Discussion Questions -

1. Why is understanding the density of water important to understanding where animals and plants live in the marine environment?
2. Float the can of Diet Pepsi and the can of Pepsi in a bucket of water. Which one sinks? Which floats? Why?
3. What was the highest/lowest densities and why do you think they were where you found them?

Estimated Time on Task -15 -20 minutes depending on age group

Connections - Salt water is more dense than fresh water and therefore in estuarine areas fresh water “floats” in a form of a “lens” over the denser salt water. In estuaries, such as New Bedford Harbor, the Taunton River and Boston Harbor, density can tell us quite a bit about how much fresh water is flowing into our coastal areas, especially after rain episodes. Because those rain episodes also carry road runoff and other wastes, being able to relate density and salinity to other observations, such as presence of bacterial contamination, is important. It also tells us something about how much fresh water is entering coastal systems. As more and more upland areas in watersheds are developed, for homes, stores and malls and other areas where soil is covered by hardtop, water runs off the land and to the sea. Some scientists believe that the growth of population in our coastal areas, and along rivers, has led to less water percolating into the ground and more entering our rivers, causing floods, or our seas, changing the freshwater/salt water balance in the sea

For Comparison and Contrast -

- Surface water from a fresh water lake - density -1.000 (approx.)
- Colder water from same lake (deeper) - greater than 1.000
- Salt water from surface (warmer) - 1.080 or more
- Salt water from depth (colder) - 1.100 or more

Links to Other Activities - Density can be compared to the findings from a salinity test kit, salinometer or refractometer (Salty Seas). Navigation exercises and locating the sampling stations relative to fresh water inflows will demonstrate the connections between marine and fresh water systems. Shoreline Survey (We're Watching You!)

allows students to connect the density study to human sources of fresh water such as waste water treatment plants.

Links to Curriculum Frameworks -

K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; analyze functional relationships to explain how a change in one quantity results in a change of another; use tables and graphs to interpret expressions, equations and inequalities; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks - Students will be asked to predict the density of sea water at various depths based on the one fact that they are given - that freshwater at 4°C has a mass of 1 gram per cubic centimeter (milliliter). The students can pose questions to be answered such as “will water at depth be more dense than at the surface and why”, “will water in the estuary be more (or less) dense than that on the open seas” or similar questions which they might answer from their observations.

Salty Seas (Salinity)

Purpose - By understanding the salinity of water we are able to make connections between physical parameters (how much salt there is in water) and the distribution of living things. Most living things live in a narrow range of temperatures and salinities. Very few organisms can move from areas of high salinity to an area of low salinity and visa versa. Salmon and eels are two examples of animals which can migrate from fresh to salt water and back. Mummichogs, or killifish, can live in a wide range of salinities, from 10 - 35 ppt but are an exception.

Key Points -

- animals and plants have evolved to live in either salt or fresh water with some exceptions which can move from one to another.
- salt water is denser than fresh water.
- salt water can be measured by observing how light bends through a prism after passing through a water sample.

Objectives -

- To determine the salinity of water at various depths and locations throughout the expedition.
- To understand the salinity of water and how it plays a role in the marine environment.

Skill Development -

- Use of collecting bottle to sample water at various depths and locations
- Use of refractometer to analyze salinity.

Materials -

- Collecting bottle for collecting at depth.
- Refractometer
- Distilled water
- Eyedropper or pipette

Station Logistics and Safety - Three students can work together on this task and then should rotate so that three recordings of data are made. Care should be taken in lowering the collecting bottle over the side so as not to fall overboard nor to scrape the hull with the bottle. Use of the collecting bottle is relatively simple but **care must be taken in the handling of the refractometer (it is parts made out of glass) and the reading of the data.**

Getting Started - Have three beakers or cups filled with water. One should have 3.5% salt, one 1.5% salt and the last fresh water. Have students look at the water and try to determine which one is salty. Ask them to invent a way to test which is saltiest, less salty and fresh. Have them test out their method. (The taste test - fingers in water and then to mouth - is okay for this test - let them know the water is clean first).

Procedures -

1. Using a navigation chart determine the location of the ship relative to the shore, to rivers nearby and to the open ocean.
2. Using a collecting bottle, collect a sample at the depth and location desired.
3. Refractometers have a flap of plastic over a glass surface. With a pipette or eyedropper, rinse the glass surface twice with distilled water.
4. With a pipette or eyedropper, drop 2 - 3 drops of sample water onto the glass surface making sure the area is covered. Close the flap making sure to remove any air bubbles and to ensure the glass surface is covered completely.
5. Hold the refractometer horizontally and bring it up to your eye. Look through the eyepiece, making sure that light can enter the other end without obstruction.
6. Peer into the eyepiece and note the location where the blue area ends and the clear or white area begins. This line corresponds to marks in the refractometer for percentage **salinity**.
7. Note the level of **salinity** and mark it down on the data sheet.
8. Thoroughly rinse off the glass surface and cover flap with distilled water, air dry both areas and return the refractometer to its case.

Findings and Observations - Your measurements will be in percentages. Make sure to mark these down to at least one decimal point. Multiply this number by 10 to convert to parts per thousand (ppt). Note the depth and location of sample taken.

What do the Findings Mean? - Sea water has a salinity of approximately 35 ppt (parts per thousand or 3.5%). Towards the equator, where there is more evaporation, the salinity rises to 37 ppt while towards the higher latitudes salinity dips to 33 ppt. Fresh water has a salinity approaching 0 ppt. In estuaries, where salt water from the ocean and fresh water from rivers mix, salinities range from marine to fresh. Due to density (salt water is denser), fresh water often sits on top of salt water in estuaries in a shape known as a wedge or lens. Samples taken at the surface of an estuary may have significantly lower salinity levels than at depth. Finding where the wedge boundary is can be one addition to this task.

Discussion Questions -

1. Why is the amount of salt in water important to living things?
2. Why does your sample have the salinity levels you measured?
3. Where did all this salt come from in the first place?
4. What is the connection between your sampling location and the salinity levels you found?

Connections - Originally, the salt in sea water was the minerals found up-land 4.5 billion years ago. Rains (fresh water) fell for millions of years washing all the soluble salts into the sea. These salts included NaCl (sodium chloride, table salt), MgCl₂ (magnesium chloride), CaCl₂ (calcium chloride), CaCO₃ (calcium carbonate) and trace salts. The seas have stayed generally the same salinity over time, with variations during ice ages (when fresh water is bound up in glaciers) when the seas were most likely saltier. Evaporation returns fresh water to clouds; rain returns fresh water to the sea directly and through runoff from the land and from aquifers.

Salt water is denser than fresh water and therefore in estuarine areas fresh water “floats” as a “lens” or wedge over the denser salt water. In estuaries, such as New Bedford Harbor, the Taunton River and Boston Harbor, salinity can tell us quite a bit about how much fresh water is flowing into our coastal areas, especially after rain episodes. Because those rain episodes also carry road runoff and other wastes, being able to relate salinity and density to other observations, such as presence of bacterial contamination, is important. As more and more upland areas in watersheds are developed, for homes, stores and malls and other areas where soil is covered by hardtop, water runs off the land and to the sea. Some scientists believe that the growth of population in our coastal areas,

and along rivers, has led to less water percolating into the ground and more entering our rivers, causing floods, or into our seas, changing the freshwater/salt water balance in the sea.

For Comparison and Contrast -

Buzzards Bay salinity	34 ppt
Slocum River (Dartmouth) salinity	5 to 30 ppt

Links to Other Activities - Salinity can be compared to the findings from the density task (Density and Destiny - Salt in Water) and from readings taken with a salt water test kit. Navigation exercises and locating the sampling stations relative to fresh water inflows will demonstrate the connections between marine and fresh water systems. Shoreline Survey (We're Watching You!) allows students to connect the **salinity** study to human sources of fresh water such as waste water treatment plants and rivers. **Salinity** can also be connected to fish sampling. Compare the **species** found with the **salinity**:

Mummichogs	5 - 35 ppt
Silversides	25 - 35 ppt
Tautog	30 - 35 ppt
Flounder	25 - 35 ppt

Estimated Time on Task - 10 - 15 minutes

Links to Curriculum Frameworks -

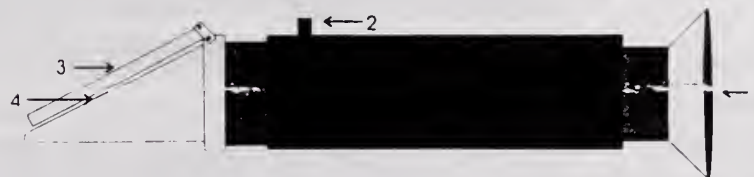
K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; analyze functional relationships to explain how a change in one quantity results in a change of another; use tables and graphs to interpret expressions, equations and inequalities; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data

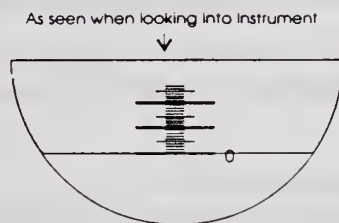
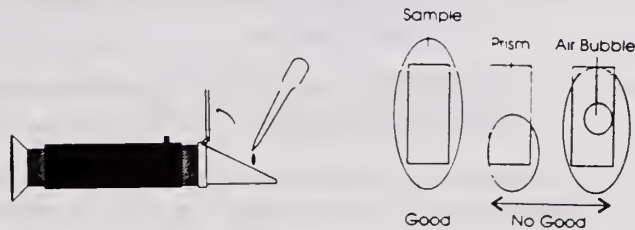
to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks - Students will be asked to predict the salinity of sea water at various depths based on their location and the testing of the known samples at the beginning of the task. The students can pose questions to be answered such as “will water at depth be saltier than at the surface and why”, “will water in the estuary be more (or less) salty than that on the open seas” or similar questions which they might answer from their observations.



PARTS OF THE INSTRUMENT

- | | |
|--------------------------|-------------------|
| 1. eyepiece | 3. daylight plate |
| 2. zero adjustment screw | 4. prism |



Breathing Waters (Dissolved oxygen)

Purpose - By understanding the amount of dissolved oxygen we are able to make connections between physical parameters (how much oxygen there is in an area or sample of water) and the distribution of living things. Of special importance is the concentrations of dissolved oxygen in two locations: in our near shore areas, such as estuaries, salt ponds and harbors, and further off shore, in deeper locations where benthic organisms dwell. Most living things live in a narrow range of dissolved oxygen. If the oxygen level sinks below a certain point, animals can suffer and die, changing the balance of nature and shifting the ecological system. and the A few organisms can move from areas of high dissolved oxygen to an area of low dissolved oxygen and visa versa, and some species can live where oxygen levels approach zero.

Studying dissolved oxygen gives us a better understanding of the impacts of humans and other animals on the sea. Dissolved oxygen is a critical indicator of water quality.

Key Points -

- animals and plants have evolved to live in areas where a limited range of dissolved oxygen concentrations are found.
- we can measure dissolved oxygen fairly easily but controlling our impacts on the amount of dissolved oxygen in water is a complex problem.
- temperature and time of day have impacts on the levels of dissolved oxygen in water.

Objectives -

- To determine the dissolved oxygen of water at various depths and locations throughout the expedition.
- To understand the dissolved oxygen of water and how it plays a role in the marine environment.

Skill Development -

- Use of collecting bottle to sample water at various depths and locations
- Use of dissolved oxygen meter and probe to analyze dissolved oxygen of water samples.

Materials -

- Collecting bottle for collecting at depth.
- Dissolved oxygen meter and probe.

Station Logistics and Safety -

Two students can work together on this task and then should rotate so that three recordings of data are made (one at the surface, one at mid water and one just above the bottom). Care should be taken in lowering the collecting bottle over the side so as not to fall overboard nor to scrape the hull with the bottle. Use of the collecting bottle is relatively simple but **care must be taken in the handling of the dissolved oxygen probe and meter - they are sensitive and break easily. Also care needs to be taken in reading of the data off the meter.**

Getting Started - Have students hold their breath and time how long they can go without air. Explain to them that animals in water face the same problem every day: the amount of oxygen in water, the same oxygen that the students breath, varies by time of day, location and amount of pollution in the water. Tell them there is a way to find out how much oxygen there is and how well animals can survive in these waters.

Procedures -

1. Using a navigation chart determine the location of the ship relative to the shore, to rivers nearby, to the open ocean and to heavy development by people on shore.
2. Using a collecting bottle, collect a sample at the depth and location desired.
3. Do not pour the sample collected into a separate container. Immediately upon bringing the sample to the surface, open the collecting bottle without agitating it, place the probe in the sample and read the dissolved oxygen level from the meter. Record this data.
4. Repeat the procedure for different depths (surface, mid-water bottom).

Findings and Observations - Your measurements will be in ppm or parts per million. A part per million is about 1 drop of water in a 1 liter beaker. Record this data over the various depths and locations of the expedition.

What do the Findings Mean? - Sea water has varying levels of dissolved oxygen based on the time of day (its lower during the day and higher at night), location, temperature of the water and other factors. Below is a chart of dissolved oxygen levels and what they mean for life in the sea.

Concentration	Impacts
0 ppm	anoxic (no oxygen - animals do not survive)
0 - 2 ppm	very low oxygen (certain worms and other infauna survive)
2 - 6 ppm	low oxygen levels (many <u>species</u> of animals survive but are stressed)
6 ppm or greater (up to 12/14 ppm saturation)	all animals thrive

Discussion

Questions -

1. Why is the amount of oxygen in water important to living things?
2. Why does your sample have the dissolved oxygen levels you measured?
3. Where did all this oxygen come from in the first place?
4. What is the connection between your sampling location and the dissolved oxygen levels you found?

Connections -

As more and more upland areas in watersheds are developed, for homes, stores and malls and other areas where soil is covered by hardtop, water runs off the land and to the sea. Some scientists believe that the growth of population in our coastal areas, and along rivers, has led to less water percolating into the ground and more entering our rivers, causing floods, or our seas, changing the freshwater/salt water balance in the sea.

Levels of Dissolved oxygen in Selected Area - Boston Harbor

	Dawn	Mid-Day
Surface	16.3	4.8
Bottom	22.4	12.4

Oxygen in water is used by bacteria in the decomposition process. In some areas, such as near waste water outfalls, uplands with fertilizer run-off, farms with manure run-off or other nutrient sources, or where road run-off carries animal waste, the amount of nutrients in the water stimulates algal

growth. As the algae die they decompose. The decomposition process uses up the oxygen and the animals in the area either move out, become stressed or can die. Some **bacteria** and animals (specifically benthic worms) can survive in low oxygen environments. Commercially and ecologically important animals, such as crustacea (crabs and lobsters) and fish, can rarely survive such conditions of low oxygen levels.

Efforts to clean up waste water and to prevent road, lawn and farm **run-off** (called **non-point sources of pollution**) have had a beneficial effect on the levels of oxygen in local waters. Boston Harbor has seen a steady rise in oxygen levels, and in the animals which require oxygen, since nitrogen-rich sludge from the waste water treatment facility at Deer Island was no longer dumped in the Harbor but was taken to Quincy to be made into fertilizer.

Links to Other Activities -

Dissolved oxygen can be compared to the findings from the minnows (Tiny Fish), crabs (Nasty, Nasty Claws) and Shoreline Survey (We're Watching You!) activities. In combination these activities should provide a basis for discussions of how what we do on the land affects what happens in the water and what lives there.

Estimated Time on Task - 10 - 15 minutes

Links to Curriculum Frameworks -

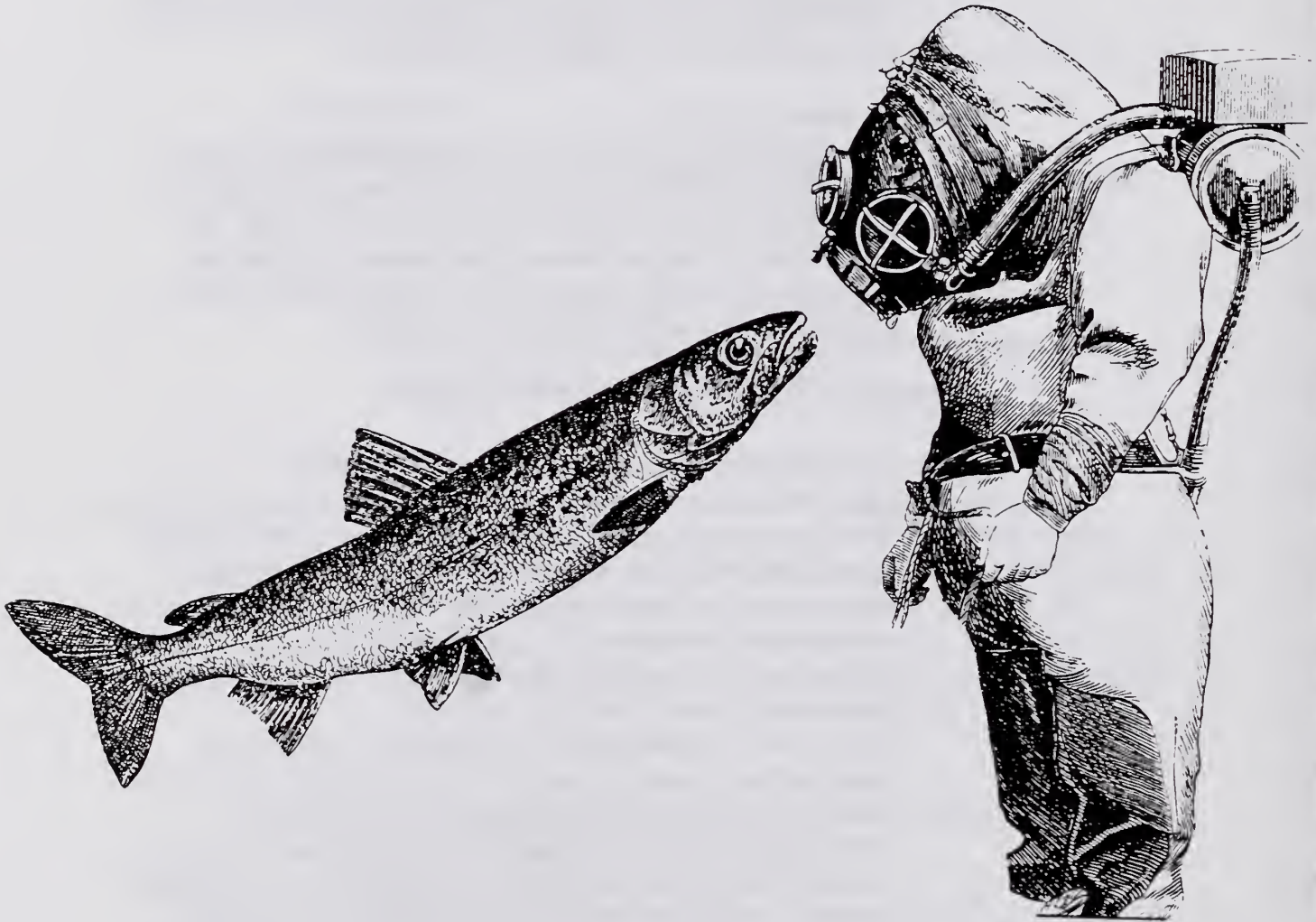
K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; analyze functional relationships to explain how a change in one quantity results in a change of another; use tables and graphs to interpret expressions, equations and inequalities; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions

about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks - Students will be asked to predict the general levels (not specific numbers) of dissolved oxygen of sea water at various depths based on their location and observations of water quality and land use. The students can pose questions to be answered such as "will water at depth have more oxygen than at the surface and why", "will water in the estuary have more (or less) oxygen than that on the open seas" or similar questions which they might answer from their observations.



Fertilizers and Limits to Growth (Nutrients)

Purpose -

By understanding the levels of nutrients (such as nitrogen and phosphorous in the form of phosphate) in sea water, we can make connections between physical parameters (such as currents), the actions of people both on land and at sea and the distribution of living things. Of special importance is the concentration of nutrients in our near shore areas, such as estuaries, salt ponds and harbors, and further off shore, in deeper locations where benthic organisms dwell. In the marine environment, the limiting factor for plant growth is nitrogen (in fresh water phosphorous plays the same role).

Most living things live in a narrow range of dissolved oxygen. If the oxygen level sinks below a certain point, animals can suffer and die, changing the balance of nature and shifting the ecological system. Too much nitrogen causes rapid algal growth (**eutrophication**) which then dies, decomposes through the action of aerobic (oxygen using) bacteria and robs the environment of free oxygen. Nitrogen can also cause rapid growth of algae such as the dinoflagellates that cause red tide.

Studying nutrients, specifically nitrogen, gives us a better understanding of the impacts of humans and other animals on the sea.

Key Points -

- marine plants (algae, eel grass) have evolved to live in areas where nitrogen is limited and serves as a limiting factor to uncontrolled growth.
- we can measure nitrogen levels relatively easily but controlling our impacts on the amount of nitrogen in water is a complex problem.
- most, but not all, additional nitrogen in the marine environment is caused by the actions, directly or indirectly, of people.

Objectives -

- To determine the nitrogen of water at various depths and locations throughout the expedition.
- To understand the nitrogen levels of water and how they play a role in the marine environment.

Skill Development -

- Use of collecting bottle to sample water at various depths and locations.
- Use of kit to analyze nitrogen levels in water samples.

Materials -

- Collecting bottle for collection at depth
- Nitrogen testing kit

Station Logistics and Safety -

Two students can work together on this task and then should rotate so that three recordings of data are made (one at the surface, one at mid water and one just above the bottom). Care should be taken in lowering the collecting bottle over the side so as not to fall overboard nor to scrape the hull with the bottle. Use of the collecting bottle is relatively simple (see collecting bottle activity). Also care should be taken with reagents used in the nitrogen test kit and they should be disposed of in a container clearly marked for waste water.

Getting Started -

Ask students what they consume for food each day. From the list ask which provide them with protein (you may need to direct younger students in this process). Ask what is the important material in protein (among many answers may be energy or building blocks for the body)

Procedures -

1. Using a navigation chart determine the location of the ship relative to the shore, or rivers nearby, to the open ocean and to heavy development by people on shore.
2. Using a collecting bottle, collect a sample at the depth and location desired.
3. Pour the sample collected into a separate container. From this container you can take samples which can be tested using the nitrate testing kit. After adding a reagent, the color of the sample is compared to the colors provided with the kit. Record the reading.
4. Repeat the procedure for different depths (surface, mid-water, bottom).
5. Dispose of the water and reagent in a waste water container.

Findings and Observations -

Your measurements will be in ppm or parts per million, or, for more sensitive kits, micrograms per liter which converts to parts per billion. A part per million is about 1 drop of water in a 1 liter beaker while a part per billion is 1/1000th of a drop of water in a 1 liter beaker. Record this data over the various depths and locations of the expedition.

What do the Findings Mean? -

Sea water has varying levels of nutrients with a range for each. Nitrogen, the important component of amino acids, proteins and genetic material, is found in the marine environment in three forms: NO₂ or nitrite, NO₃ or nitrate and NH₄ or ammonium.

When we test water for nitrogen we are usually measuring the amount of nitrogen within each or one of these molecules. The calculations we make are based on the amount of nitrogen, not necessarily the form in which it is found. Also, nitrogen is found in fertilizers, human wastes and other sources in one of these forms so measurement can be tricky if we test for a specific form rather than for nitrogen in general. Normal ranges for the two most common forms found in the marine environment are:

Form	Range
NO ₃ or nitrate	.1 - 5000 ppb (or micrograms/liter)
NH ₄ or ammonium	5 - 50 ppb (or micrograms/liter)

Discussion Questions -

1. Why is the amount of nitrogen in water important to living things?
2. Why does your sample have the nitrogen levels you measured?
3. Where did all this nitrogen come from in the first place?
4. What is the connection between your sampling location and the nitrogen level you found?

Connections -

As more and more areas in watersheds are developed for homes, stores and malls and other areas where soil is covered by hardtop, more water will run off the land and to the sea. Some scientists believe that the growth of population in our coastal areas and along rivers has led to increased nutrients entering into coastal waters. The major limiting factor to algal growth in coastal waters is nitrogen (in fresh water it is mostly phosphorous). When excessive levels of nitrogen enter shallow coastal waters, it can stimulate an acceleration of a process called eutrophication.

In eutrophication, a body of water has rapid, excessive growth of algae. If eel grass grows in that area the free floating forms of algae can shade the sunlight that these plants need to survive and attached algae can coat eel grass also stifling its growth. Eel grass is the preferred habitat for young scallops, food for geese and ducks and the haunts of young fish as they grow. Excessive levels of nitrogen can also affect the growth of algae away from shore. The algae that cause red tide appears to be stimulated by runoff from land carrying nitrogen.

In some areas, such as near waste water outfalls, uplands with fertilizer run-off, farms with manure run-off or other nutrient sources, or where road run-off carries animal waste, the amount of nutrients in the water stimulates algal growth. As algae die they decompose. The decomposition uses up the oxygen and the animals in the area move out, become stressed or can die.

Efforts to clean up waste water and to prevent road, lawn and farm run-off (called non-point sources of pollution) have had a beneficial effect on the levels of oxygen in local waters. Boston Harbor has seen a steady rise in oxygen levels and in the numbers of animals which require oxygen since nitrogen-rich sludge from the waste water treatment facility at Deer Island was no longer dumped in the Harbor but was taken to Quincy to be made into fertilizer.

Links to Other Activities -

Nitrogen levels can be compared to the findings from the Minnows, Crabs and Shoreline Survey activities. The Dissolved Oxygen activity should be used in conjunction with nutrients and the two used to determine environmental health of the area under study. In combination these activities should provide a basis for discussions of how what we do on the land affects what happens in the water and what lives there.

Estimated Time on Task - 10 - 15 minutes

Links to Curriculum Frameworks -

K - 4 - Plan and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; interpret finding by relating one factor to another.

5 - 8 - note and describe relevant details and relationships; identify, describe and create a wide variety of patterns; use patterns and relationships to explain how a change in one quantity results in a change of another; use tables and graphs to interpret expressions, equations and inequalities; describe ranges in data when patterns are not exact; analyze alternative explanations and procedures.

9 - 12 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks -

Students will be asked to predict the general levels (not specific numbers) of nutrients in sea water at various depths based on their location and observations of water quality and land use. The students can pose questions to be answered such as "will the water at depth have more nitrogen than at the surface and why?", "will the water in the estuary have more (or less) nitrogen than on the open seas?" or similar questions which they might answer from their observations.

It's Cold Down There (Temperature)

Purpose - Animals and plants in the sea have evolved to tolerate or thrive in different temperatures. Some organisms can survive for extended periods in very cold, nearly freezing waters. Others are unable to tolerate the cold and must remain in warmer climes and waters. Just as warmer water is equated with further south, so to is colder water equated with depth.

By studying water temperature we get a better picture of how variable the seas are, from near shore to off shore and from the surface to the **benthos**.

Key Points -

- water gets colder as you go deeper
- water gets colder, generally, as you move away from shore
- water temperature is one controlling factor on where animals and plants live

Objectives -

- To measure temperature both at the surface and at depth.
- To use thermometers.

Skill Development -

- Use of thermometers.
- Use of collecting bottle.

Materials -

- water collecting bottle
- thermometer
- blubber glove
- bucket of cold water

Station Logistics and Safety - Two - three students can work together on this task and then should rotate so that three recordings of data are made. Care should be taken in lowering the water collecting bottle over the side so as not to fall overboard nor to scrape the hull. Thermometers are simple to use but care must be taken in handling them as many varieties are breakable.

Getting Started -Have students put on the blubber glove and then put their hand in a bucket of cold water (ice water is best). The glove will insulate their hand from the cold. Have them touch the water without the glove to see how cold it gets. Tell them they are going to find out how cold it gets as you go deep into the sea.

Procedures -

1. Using a water collecting bottle collect a sample at the surface of water and immediately test this sample for temperature by placing the thermometer directly into the sampling bottle and recording the temperature. This test is the only exception to using the collecting
2. bottle for testing the sample.
3. Repeat the same procedure for at least two locations. One location should be close to the bottom of the water where the samples are being taken and a third midwater.
4. Repeat the above at other depths as time allows.
5. Record the temperatures and depths.

Findings and Observations -Record the location temperature, and depth of the water. Data can be recorded in a variety of manners based on the type of cruise or program. Vertical data (temperature at depth) gives a two dimensional image of temperature distribution. Temperatures can also be taken over the length of a voyage, at certain times of day, or at specific targeted locations during the voyage. The data collected can be graphed using either a combination of depth vs. temperature, location vs. temperature or, using a computer which is capable of displaying three dimensions, location vs. temperature vs. depth, a true profile of the waters through which the vessel travels.

Discussion Questions -

1. Why did water temperature change as you went deeper or from place to place?
2. If this testing was repeated at a different time of day would the results be the same? Why/Why not?
3. Was there any dramatic change in temperature as it was studied at depth? What would explain this change?

Estimated Time on Task - 5 - 10 minutes depending on age

Connections - Changes in water temperatures have been shown to be a major global environmental issue. As greenhouse gases (carbon dioxide and methane, among others) concentrate in the atmosphere, the global mean (average)

temperature is expected to rise. How much, not whether, is the question. Understanding what the temperatures are in a given area may not provide the information for long term study of global change but it demonstrates the importance of temperature in this system.

Temperature has a great deal to do with where organisms live and how much mixing takes place in the seas. This latter point is very important for understanding why northern waters are so productive while tropical waters have the look of sterility about them, except around shores and reefs. Cold surface air chills surface waters which sink, deeper waters rise and a mixing of waters, with nutrients from the deep, takes place. This mixing provides nutrients for plankton, especially phytoplankton, at the base of a food pyramid in the sea. This enriched environment eventually lead to the incredible populations of fish at the Grand and Georges Banks.

As global warming progresses, the seas will become warmer, the areas where mixing doesn't take place may expand, and the polar ice caps may partially melt, adding billions of gallons of fresh water to the marine environment. The implications of this major ecological shift are only partially understood.

The seas can also be "contaminated" by changes in temperature due to other human actions. Water is used to cool energy generating plants, such as nuclear power plants, and the warm water from these plants is dumped back in to the sea. Lobsters thrive in these areas growing more quickly to adult/breeding size.

Surface Ocean Temperatures (in degrees Celsius)

Latitude	Atlantic Ocean	Indian Ocean (South)	Pacific Ocean
70° - 60°	5.60°	-1.50°	-1.30°
60° - 50°	8.08°	1.63°	5.74°
50° - 40°	13.16°	8.67°	9.99°
40° - 30°	20.40°	17.00°	18.63°
30° - 20°	24.18°	23.38°	22.53°
20° - 10°	25.18°	25.85°	26.42°
10° -	26.66°	27.41°	27.20°

Links to Other Activities - Use of the hydrometer (Density and Destiny) relates the salinity and temperature of waters to water density.

Links to Curriculum Frameworks -

K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; interpret findings by relating one factor to another.

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9 - 10 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks - Students will be asked to estimate what temperature water is at the surface and how much that temperature might change as samples are taken deeper and deeper in the water. They will predict the changes in temperature and then test their predictions. They will be able to ask question such as “why is water at depth a different temperature?” and “what does temperature and organism distribution have in common?”



What Colors Am I? - The Forel Ule Scale

Purpose - Substances in the environment, both naturally occurring and produced as a result of human activity, have characteristic colors. We think of the sky as blue, and yet it can be gray, black, even pastel shades or brown, depending on time of day, weather, air pollution and other factors. Many of these factors are materials which cause the sunlight passing through the sky to refract (bend) or be absorbed, leaving other wavelengths of light to be reflected. These are the wavelengths we see and which give the sky its characteristic colors.

Water in the marine environment also has characteristic colors, with the “true color” found when all sediments are removed and the “apparent color” being when all suspended particles and other materials are still present.

Key Points -

- as light penetrates through water it reflects off of suspended
- particles and dissolved substances.
- many of the dissolved substances are indicators of life in the water or water contamination
- much of the color of water in coastal areas is caused by what people do on land nearby and in watersheds upstream

All these factors contribute to the distribution of fish, for example, as denser populations of commercially valuable fish are found in colder, northern waters, with their high nutrient levels and fewer, less dense fish populations are found in tropical waters.

Objectives -

1. To determine the apparent color of water in a sample.
2. To relate the apparent color of water to suspended materials (turbidity) in water.
3. To relate the color and turbidity to on-shore activities of people.

Skill Development -Use of the Forel Ule Scale and use of Collecting Bottle to collect water.

Materials -

- Water sampler (Collecting Bottle)
- Forel Ule Scale
- Recording Sheet

Station Logistics and Safety - Three students can work together on this task and then should rotate so that three recordings of data are made. Care should be taken in lowering the collecting bottle over the side so as not to fall overboard nor to scrape the hull with the bottle. Use of the collecting bottle is relatively simple but care must be taken in the handling of the Forel Ule Scale (it is made out of glass) and the reading of the data.

Getting Started - Have students look at the sky and note the color. If blue, ask them why, ask them what does a gray sky imply, what does a brown sky imply? Ask them to predict the weather based on a sky color. They then should transfer this information to the water study.

Procedures - (This task can be done on any side of the ship by a team of three students.)

1. Each student should take a turn collecting a sample, testing the sample for color with the Forel Ule Scale, and recording the data. Follow the instructions for use of a collecting bottle (see Water Samples from the Deep). Different bottles have different ways for closing when the depth you want to sample is reached. At least three samples should be taken; one each at the surface, at midwater and near the bottom.
2. Pour a sample of the water into the glass tube which accompanies the scale. Compare the sample taken to the scale and record the data.
3. Repeat at three depths or different locations.

Estimated Time on Task - 5 - 10 minutes depending on age group

Findings and Observations - Record the location, temperature and color of the water. Data can be recorded in a variety of manners based on the type of cruise or program. Vertical data (color at depths) gives a two dimensional image of density distribution. Colors can also be taken over the length of a voyage or at specific targeted locations during the voyage. The data collected can be graphed using either a combination of color vs. location. A comparison of data with that from the SECCHI disc task can be made.

Discussion Questions -

1. Why do you think the water was colored as it was?
2. Are there any reasons in the local area (on shore, on water) to help explain why the water might have this color?
3. What different colors were present in different samples? How would you explain the differences?
4. Why do more samples help us get better information and add to the information on which decisions are made?

Connections - Historically, the coasts were much less developed and the actions both on shore and on the water were less likely to cause significant environmental impact. Sailing ships churned up the water less than the propeller driven craft of today, so it is likely that people making observations of water quality historically would not have had to deal with suspended sediments from these sources. In contrast, however, actions along the waterfront, and upland in the watersheds, were probably not as well managed to prevent drainage from development and construction, from household and sanitary wastes, from agriculture and industry, from entering into our near shore waters.

Free-floating, or planktonic, algae, are a significant problem in northern waters when they grow in excessive amounts due to human actions, such as fertilizer run off, nitrogen from sanitary wastes, manure run off from farms and even acid rain.

State and federal agencies, local environmental groups, and others are concerned about sediments, light penetrance and what these factors mean in the aquatic environment. As more and more people have moved into our coastal zones, the coastal regions have come under increased pressure from the impacts of human actions. Nutrients and sediments are two indicators of these pressures. Observing color helps us understand what is in the water and in what concentrations.

The Massachusetts Bays and Buzzards Bays National Estuary Programs are especially concerned about algae growth, and for two reasons. The first is that excessive growth cuts out the light to eelgrass beds, a very important coastal habitat for young fin and shellfish. The second is that excess nutrients, especially nitrogen, seems to stimulate the growth of red tide algae and can lead to paralytic shellfish poisoning. As more people have moved to the coastal zones, and as this population continues to

rise, these problems will continue. New methods of waste water treatment, methods for preventing farm runoff and runoff during construction projects in watersheds all will contribute to improved coastal water quality.

For comparison and contrast: In general, the blue or blue green water which we often equate with clean or tropical waters, is water without impurities. Tropical water temperature stays the same as you go deeper and does not mix the top and bottom waters regularly. Nutrients in deeper waters tend to stay there. Therefore the water is clear, blue and relatively devoid of life (except around reefs). In the tropics, very few nutrients are found in the water, coastal erosion is more widely distributed, and coastal runoff, a growing problem, effects mostly near shore areas. Around Cancun, Mexico, for example, the waters once were clear, blue and visibility was for many meters. Development, boats, excess nutrients, and pollution and natural sources such as storms and decaying mangrove leaves, have contributed to make the water more murky and less characteristically clear.

In contrast, in northern regions, dead and decaying leaves (humus) and nutrients from the uplands wash into the sea. They give the water yellow green or brown colors and stimulate the growth of algae. The annual mixing of surface and deeper waters (due to variations in temperatures throughout the year) stimulate the growth of algae which give northern waters their characteristic green color. Algal blooms, such as red tide, take place in areas where excess nutrients stimulate the rapid growth of species of dinoflagellates (plankton) which have characteristic colors and contain deadly endotoxins. When absorbed by shellfish, which bioaccumulate

Links to Other Activities - The SECCHI Disk task (Sediments, Sunlight and SECCHI Disks) complements this task by adding the dimension of turbidity and sunlight penetrance through water, the Nitrogen Enrichment Task (Fertilizer EVERYWHERE), and the Shoreline Survey (We're Watching You!) add to the information on which decisions are made.

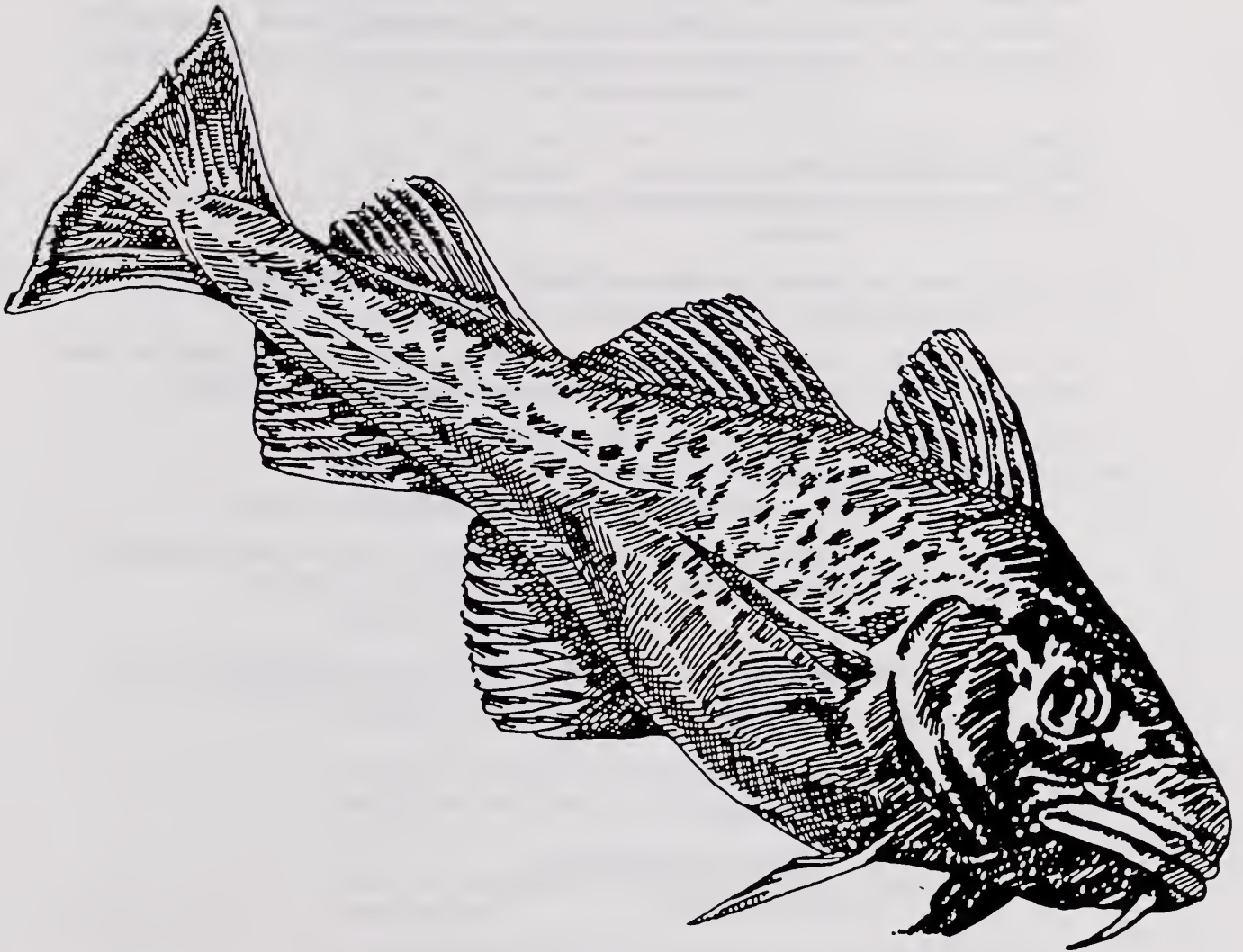
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5 - 8 - note and describe relevant details patterns and relationships; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 formulate testable questions and generate explanations using the results of predictions; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Applications of Frameworks - Students will be asked to predict the color of sea water at various locations along the voyage and to pose questions as to why the water is colored as it is, what the sources of the colors are and what the various colors mean.



Sediments, Sunlight and SECCHI Disks

Purpose - By knowing how far light penetrates into the water we are able to get a comparative estimate of the amount of suspended solids (particles in water), algae and other **plankton** in the water column. In ocean water, clear water can be relatively nutrient poor (as in the tropics). Very dark waters (where light penetrates only a short distance) can have too many **nutrients** causing blooms of microscopic algae. Other very dark waters could be caused by too many **sediments** from the **watershed** or from activities which stir up the **benthos** (in shallow water). This information can help us understand the connections between the land and the sea. **Run-off** from the land in **watersheds**, often as a result of human actions such as development, becomes the **sediments** and **nutrients** which effect the **ecology** of the marine environment.

Key Points -

- as light penetrates through water it reflects off of suspended particles
- more suspended particles in water (higher **turbidity**) mean that light will stop at a shallower depth
- much of the **turbidity** of water in coastal areas is caused by what people do on land nearby and in **watersheds** upstream

Objectives -

- To determine how far light penetrates in the water.
- To observe the importance of redundancy to develop reliability in testing.

Skill Development - Use of a SECCHI Disk. Measurement and recording of depths.

Materials -

- SECCHI disk
- Weighted, graduated line
- Recording chart

Station Logistics and Safety - Three students can work together on this task and then should rotate so that three recordings of data are made. Care should be taken in lowering the SECCHI disk over the side so as not to fall overboard nor to scrape the hull with the disk or the weight. Use of the

SECCHI disk is relatively simple but care must be taken in the reading of the data.

Getting Started - Ask the students how far into the dark they would have to go at night before someone would not be able to see them with a flashlight. Tell them that life in the sea has the same problems as they do at night - light only goes so far through a medium such as water or air. It reflects off of surfaces as it goes, even if those surfaces are just particles in the air or water.

Procedures - This task should be done on the side away from the sun to prevent the data be skewed by glare or reflections.

1. Before starting, measure the distance between the disk and the first mark on the line and note this distance. Then measure the distance between each mark on the line thereafter. Note this distance - it is the unit of measurement which will be used to determine depth of disappearance - add the first measure to the multiples of the unit for total depth..
2. Tie the line securely at the end of the SECCHI disk to a cleat or other part of the ship. With one student holding the disk away from the hull, carefully lower the disk into the water never letting go of the line.
3. The second student should watch the disk and when the disk can no longer be seen the line should stop being played out.
4. The marker on the line should be noted and the amount of line length underwater called out to the third student for recording.
5. The same procedure should be repeated three times with each student taking turns to read the length of line and playing the line out over the side.

Findings and Observations - Record depths at which the SECCHI disk disappears.

Discussion Questions -

1. Why do you think the SECCHI disk disappeared the way it did?
2. Are there any reasons in the local area (on shore, on water) to help explain why the SECCHI disk disappeared when and where it did?
3. What was the deepest depth at which the SECCHI disk disappeared?
4. What was the shallowest depth at which the SECCHI disk disappeared?
5. How would you explain the difference between the different measurements?
6. Why do more samples help us get better information upon which to make environmental decisions?

Estimated Time on Task - 5 - 10 minutes depending on age group

Connections - State and federal agencies, local environmental groups, and others are concerned about sediments, light penetrance and what these factors mean in the aquatic environment. As more and more people have moved into our coastal zones, the coastal regions have come under increased pressure from the impacts of human actions. Nutrients and sediments are two indicators of these pressures.

Excessive sediment or turbidity can be indicators of upland or shoreline erosion, or one of the biggest concerns for environmental scientists, nutrient enrichment of our near-shore waters. Algae blooms, especially free floating algae which includes the algae which cause red-tide and paralytic shellfish poisoning, are connected to too much nitrogen in the marine environment. Determining light penetrance, when added to color, tells us quite a bit about what is occurring in the local area.

For Comparison and Contrast (how much light disappears as you dive)

Depth	Pure Sea Water	Ocean Water	Coastal Water Clear	Coastal Water Turbid
1 meter	62%	65%	74%	77%
5 meters	74%	83%	94%	97%
10 meters	78%	92%	99%	99.5%
50 meters	93%	99.7%	100%	100%

Links to Other Activities - The Forel Ule Scale Task (What Colors Am I?) complements this task by adding the dimension of color (presence of algae or contaminants), the Nitrogen Enrichment Task (Fertilizer EVERYWHERE), and the Shoreline Survey (We're Watching You!) add to the information on which decisions are made.

Links to Curriculum Frameworks -

K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; describe ranges in data even when patterns

are not exact; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks - Students should be asked to predict at what depth the SECCHI Disk will disappear. They should pose a question, such as "why does light penetrate only so far in these waters" or similar questions that they might answer after performing this task.



Ocean's Bottom - Exploring the Benthos -

Purpose -

By understanding the number and kinds of animals, including fish and invertebrates, which inhabit the bottom of the sea, and the sediments in which they live, we can get a more accurate understanding of the complex relationships between materials, organisms and human impacts. With this information we can begin to build a food web of the bottom of the sea. We can also understand the importance of oxygen to animals and their lives.

Key Points -

- animals have evolved to live in or use the bottom of the sea (the benthos) some spending their entire lives there, others using the bottom in adult stages, others only when danger threatens.
- some animals feed on dead and decomposing plants and animals, helping cycle materials through the marine environment.
- a sample of the benthos can tell us much about the sources of sediments which make up the ocean's bottom.

Objectives -

- To sample the benthos and identify the sediment types
- To capture and identify animals which live in the benthos
- To understand the relationship between abiotic factors and the distribution and number of animals in the marine environment.

Skill Development -

- Use of bottom grab or corer
- Use of hand lens or microscope (dissecting)
- Use of Field Guides and keys

Materials -

- Bottom grab or corer.
- Invertebrate identification guides (Peterson Guide to the Atlantic Seashore, National Audubon Guide to Atlantic Seashore Creatures)
- Hand lenses
- Microscope (dissecting)
- Examination tray
- Sieve Set

Station Logistics and Safety -

Begin this task when the ship is stopped at a sampling site. The number and diversity of animals varies greatly from place to place. Care should be taken in handling the bottom grab or corer. Both are very heavy and may require crew assistance. Be careful that hands are not caught in the grab or corer in the moving parts which close. Lower the grab or corer over the side so as not to fall overboard nor to scrape the hull with the trap. Use of the grab or corer is relatively simple but the sample will be heavy and messy. After handling samples from the benthos, students should wash their hands thoroughly in antiseptic soap (unless the sample is being taken far from shore). Some areas have bacterial or chemical contamination and sediments should be treated as if contaminated. This activity is best done amidships where the deck can be easily washed off and hauling can be aided by lines run through block and tackle.

Getting Started -

Ask students what lives in the bottom of the seas in their area. Ask them what they eat from the sea. Ask them to identify which of these might live in or on the bottom. Ask them to predict what they might catch with this grab or corer.

Procedures -

1. Using a navigation chart determine the location of the ship and the type of bottom where the sampling will take place. Determine the location of the ship relative to the shore, to rivers nearby and to the open ocean. Using the fathometer, determine the depth in the area. A soft bottom is needed for this activity. Rocky bottoms may snag or damage the samplers and will produce little if any results.
2. The bottom grab is hinged and a latch is provided which prevents closure until the grab hits bottom. If a corer is being used this will have a safety catch on it which needs to be set in advance of lowering it over the side. Make sure lines holding the grab or corer are securely attached.
3. Securely attach the loose end of the line to a cleat or other point on the ship. If a block and tackle is available run the line through first and then attach to a cleat. Lower the grab or corer over the side VERY CAREFULLY. Allow the grab or corer to freely drop to the bottom. Note the depth from the line attached.
4. Pull the grab or corer from the bottom. This may take several people as the sampler will be filled with sediments and water. Carefully hoist the grab or corer over the side.
5. If time allows, resample at different locations.
6. Open the grab into a very large bucket or tray (a wooden tray can be made to prevent damage to the deck but the one short side

should be hinged to allow for rinsing the sediments back to the sea. Be careful with fingers as the grab is opened. Open the corer and using a pole or plunger push the core out into a tray or the deck.

7. Observe the sediments. Note smell, color, zonation (with the corer), location of animals or plants, texture (rub some of the sediments through fingers) and size of particles. Pass a sample of the sediments through a sieve set to determine grain size. Coarse grains allow for greater passage of materials and animals through the sediments while finer grains are denser, heavier and can hold higher concentrations of contaminants such as heavy metals.
8. Using field guides, identify the species of animals collected and the number of each species. Record this information.
9. Clean the grab or corer with sea water and rinse the animals back into the water with the sediments.

Findings and Observations -

Below is a list of some of the animals which you are likely to find in a benthic sample in this region. Other animals are possible, including, but not limited to octopus(!), other crabs, small lobsters and the young of other fish species.

- American eel
- green crabs
- rock crabs
- spider crabs
- sand shrimp
- shore shrimp
- oysters
- quahog clams
- razor clams
- scallops
- soft shelled clams
- various segmented worms
- round worms
- tube worms

Sediments may contain organic materials (dead and decomposing animals and plants) and grains of various sizes and types. Included are clays (finest particles), fine sand, sand and coarse sand. The materials in sand can be observed with a hand lens or dissecting scope and different minerals identified. The most common in this area being quartz, feldspar, mica, and other silicates.

What do the Findings Mean? -

Fish and invertebrates in this region can be indicators of a variety of environmental factors. Too little dissolved oxygen and the fish and invertebrates listed above begin to disappear. Some will be replaced by other animals, such as worms, but others will not have ecological replacements.

Compare the animals found to the location of the ship relative to shore, to the salinity and dissolved oxygen levels at the depth where the animals are found, and to the plankton and other food in the water.

Discussion Questions -

1. Why did you find the animals you caught in the location where you caught them?
2. What were the sediment types (grain size, color, aroma) and from what sources did the sediments come?
3. What environmental conditions must your animals be adapted to in order to survive?
4. What is the connection between your sampling location, the abiotic factors (salinity, temperature, dissolved oxygen levels) and the animals you found?

Connections -

The benthos has been impacted greatly by the activities of people, sometimes directly, such as in dragger fishing, and sometimes not so obviously, such as a result of human wastes and runoff entering the sea. The bottom of the sea is the place where so many commercially important species live. Flounder, lobster, crabs, scallops and other shellfish inhabit this zone. Scallop dredges and other fishing techniques which drag along the bottom indiscriminately capture benthic animals while churning up the sediments, at times mixing layers which have taken hundreds of years to create. Non-target species are often captured. Many die in the capture and handling process. Some are thrown back, where survival rate is relatively low. Dragnets and dredgers don't mean to cause this destruction but these fishing

practices are some of the oldest fishing technologies and efficient means for retrieving food from the sea.

More problematic, long term, is the addition of nutrients, often from human wastes, to the benthic environment. As nitrogen (from septic or fertilizer) enters into the sea it stimulates algal growth. As the algae grows and dies it settles to the bottom. There aerobic (oxygen using) bacteria decompose the algae consuming oxygen in the process. This oxygen is not readily replaced and the benthos shifts from one rich in oxygen to one depleted of oxygen. When this happens anaerobic (without oxygen) conditions occur, killing most of the benthic organisms which are of value commercially or which play a role in the “normal” ocean food web. New, less valuable organisms enter these “dead” or anaerobic zones and live in these anaerobic sediments. Deep areas of both Buzzards Bay and Long Island Sound have been found to be anaerobic or shifting in that direction. Hence the importance of monitoring nutrients and dissolved oxygen levels in marine studies.

Links to Other Activities -

Animals caught can be compared to the findings from the salinity (Salty Seas) and dissolved oxygen (Breathing Water) tasks.

Different collecting techniques can be compared such as crab traps (Nasty, Nasty Claws) and plankton tows (Free Floaters). Navigation exercises and locating the sampling stations relative to fresh water or septic inflows will demonstrate the connections between marine and fresh water systems, the actions of people on land and the animals that live on the bottom. Locating waste water treatment plants is important to understanding how nutrients flow into the sea.

Estimated Time on Task - 15 - 30 minutes

Links to Curriculum Frameworks -

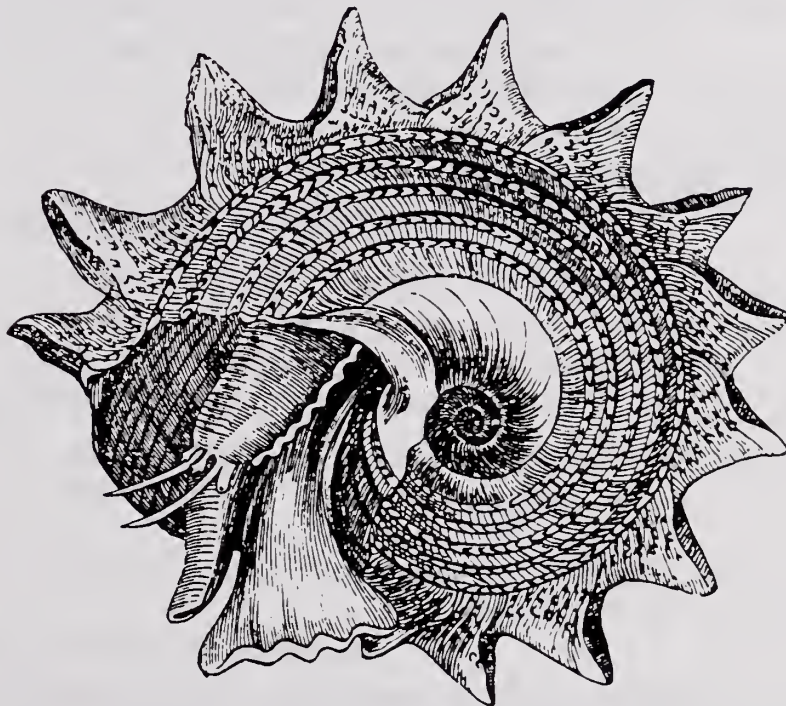
K - 4 - Planning and conducting a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; analyze functional relationships to explain how a change in one quantity results in a change of

another; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures. **9 - 10** - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks -

Students will be asked to predict what animals they may find on the bottom at their location. The students can pose questions to be answered such as "what animals are here and why", "how does the level of dissolved oxygen or fishing activity effect what we find in our samples? or similar questions which they might answer from their observations.



Moving Waters (Currents and Motion)

Purpose - Where do my sanitary wastes go once they hit the ocean? Why is the weather in southern New England so much warmer than just a few miles north? Why do you need to carefully time when you will try to sail through the Cape Cod Canal or Woods Hole? Why are subtropical species of fish found in summer in New England waters?

These questions and many others regarding the coasts of Massachusetts can be answered by understanding currents.

Key Points -

- the motion of water from place to place in the ocean is a current.
- the rate at which a current is moving has an impact on the life in the area and on ships which sail through the current.
- currents have been responsible for the distribution of life around the world and affect weather and climate.

Objectives -

- To determine the currents which surround the boat.
- To understand what currents are and how they can effect the ship, and the environment.

Skill Development -

- Use of a drogue or float to determine currents or ship velocity.
- Use of stop watch to time drogue actions.

Materials -

- Drogue (see below for instructions) or other float
- Stopwatch
- Tape measure
- Gaff
- Light weight line

Station Logistics and Safety - Three students can work together on this task and then should rotate so that three determinations of the rate of the current around the boat are made. Care should be taken in lowering the drogue or float into the water and especially in attempting retrieval so as not to fall overboard. Each student should take a turn at each stage in the task (release, time, retrieve).

Getting Started - Ask students if they have ever been in a crowd of people moving from place to place, such as leaving a ball game or school event. Ask those who have, what it would be like to move in the opposite direction of the flow of people. Tell them the same applies in the water, but instead of a flow of people, the flow is of the ocean's water moving from place to place.

Procedures - This task can be used to determine the rate of ship motion or can be used on shore programs. To determine current, the ship must be stopped. To determine rate of motion, the ship should be underway. The actual speed of the ship will be the motion through the water and through the current.

1. Set a distance, such as 60 feet, as a start and stop point is set for release and retrieval of the drogue or float. This distance is approximately 1/100 of a nautical mile (6080 feet to a nautical mile; 1 nautical mile per hour = 1 knot).
2. One student serves to release the drogue or float at a point beyond or before the starting point for timing. This allows the drogue or float to hit the water, float to the surface and begin moving at a constant speed, prior to sampling. As the drogue or float passes the starting point the water, the stopwatch is started by the second student and timing begins. The line, attached to the drogue must play out freely, if a line is used.
3. When the stop point is reached the third student calls out and the stop watch and timing are stopped. Immediately the third student retrieves the drogue or float with the gaff and returns it to the boat, if possible. The line attached should be used as a safety so that the drogue or float is not lost.
4. The time for the task is recorded and the students rotate from position to position taking three measurements and recording the estimated rate of current using the following formula:

Rate of current = distance measured/time (in feet/second)

This figure can be converted to miles per hour.

Making a simple drogue/float:

1. Use an empty one gallon plastic jug. Fill the jug approximately 1/2 - 2/3 with clean dry sand.
2. Take a cork (which completely fills the jug opening) and make a 1/8" hole with a drill or auger through the length of the cork. Temporarily push the cork into the jug and float in a bucket of water. The unit should float 75 - 90% below water level. If it

floats higher it will be effected by winds. If it floats too low it may be difficult to retrieve.

3. Take a coat hanger and bend the hook straight and the loop elongated.
4. Push the straight part of the hanger through the cork and bend the end around so it cannot be removed.
5. Push the cork into the jug opening and seal with wax, epoxy or layers of duct tape. Submerge the unit to make sure there are no leaks and redo if leaks are present.
6. Practice catching and lifting the drogue/float prior to use on the boat to make sure it is not too heavy or difficult to retrieve.

Findings and Observations - Record the direction and speed of the drogue or float as a measure of current. Note any observations which would effect the drogue or float from moving freely along its length of line. This task can also be done with a grapefruit, a balloon filled with water, or to model seed migration in the tropics, with a coconut! These items, however would be difficult to retrieve and under no circumstances should the balloon be allowed to remain in the water (can cause mortality in turtles and other marine animals). Longshore currents can also be studied in the same manner as above using either the drogue or float or the other items listed. Toss the item into the water and track its motion, relative to shore either for a set distance (record time) or for a set time (record distance). Converting the data to miles per hour may have more meaning for students than feet per second.

What do the Findings Mean? - Currents play a major role in where animals and plants live and how ships move from place to place. One of the world's largest currents, the Gulf Stream is as much as 150 km (90 miles) wide, as much as 800 m (2,500 feet) deep and flows at a rate of 250 cm/sec (5.5 miles per hour) from Florida along the Atlantic seaboard and to England, where it tempers the climate. Other currents, such as through the Cape Cod Canal, are so strong as to require ships to schedule their passages to times when the current runs in the same direction as the ship's. Currents flowing out of Buzzards Bay can exceed 1.0 mile per hour. Other strong currents are seen around islands, in Vineyard Sound and as tides enter and depart the numerous estuaries in the region.

Discussion Questions -

1. Why is an understanding of currents important to understanding where and how things live in the sea.?

2. What was the rate of current? How does this compare to the speed at which the boat moved to get to your sample site?
3. Why were there differences (if there were) in the speeds recorded for each of your samples?
4. How might the sampling been made more accurate?

Connections - Currents can help us understand the impacts we have and can potentially have, from our actions on the land or on the water. Studies of currents in Massachusetts Bay, for example, demonstrated that the waste water from Boston and vicinity should not effect the Cape Cod Bay area - the currents bring the water from Massachusetts Bay out to sea north of Race Point on Cape Cod. Currents also bring the water from the Merrimack River around Cape Ann and to Massachusetts Bay. Warm water gyres (circular currents) form and break off the Gulf Stream and give southern New England its more temperate climate, as compared to the rest of the region.

By understanding how and where waters move, we can understand many aspects of life in, on and around the sea. For thousands of years, currents have been critical to the distribution of people, as they make their way on ships around the world on voyages of discovery, fishing, or migration. Major currents, such as the Gulf Stream also determine where people can live, as these currents bring with them weather, either warm and moist, or cool and damp. Currents affect storms, salinity, pollution distribution and many other global and local environmental concerns.

Currents also determine where and how other living things live in the sea. Currents bring the nutrients from near shore including those that run off from our watersheds, to the sea and then control how those materials will be mixed in the sea. Currents have an impact on fisheries. A good example is the anchovy fishery of Chile which collapsed when a warm water current, El Nino, changed the currents bringing the nutrients needed by the food of anchovies to the coast of Chile. Its thought that currents in the Pacific brought the ancestors of the giant tortoises and marine iguanas to the Galapagos Islands!

Links to Other Activities - The Shoreline Survey (We're Watching You!) is important for understanding the human derived inputs into the sea. Currents distribute and circulate the substances which run off the land or are dumped at sea and therefore these two activities are linked.

Estimated Time on Task - 5 - 10 minutes

Links to Curriculum Frameworks -

K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks - Students will be asked to predict the speed of the ship or the speed of the current, based on their knowledge of how fast they go on a bicycle (up to 20 miles per hour), in a car (up to 70 miles per hour), or walking (up to 4 miles per hour). The students can pose questions to be answered such as "how does current affect the rate at which the ship moves through the water?" or "how fast is the current as compared to how fast the ship moves?" or similar questions.

1996 CURRENT TABLE CAPE COD CANAL At R.R. Bridge												
Standard Time JANUARY						Standard Time FEBRUARY						
CURRENT TURNS						CURRENT TURNS						
EAST Flood Starts			WEST Ebb Starts			EAST Flood Starts			WEST Ebb Starts			
a.m.		p.m.	Kts.	a.m.		p.m.	Kts.	a.m.		p.m.	Kts.	
DAYS OF THE MONTH	DAYS OF THE WEEK			DAYS OF THE MONTH	DAYS OF THE WEEK			DAYS OF THE MONTH	DAYS OF THE WEEK			
1	M	12 36	12 15	3 9	6 05	6 41	a4 2	1	T	12 58	1 28	p4 0
2	T	1 26	1 08	p4 0	6 56	7 34	a4 3	2	F	1 46	2 12	p4 1
3	W	2 11	1 54	p4 1	7 42	8 22	a4 4	3	S	2 29	2 52	p4 2
4	T	2 52	2 37	p4 2	8 26	9 05	a4 4	4	S	3 08	3 30	p4 3
5	F	3 31	3 16	p4 2	9 06	9 46	a4 5	5	M	3 45	4 06	p4 3
6	S	4 08	3 53	p4 3	9 45	10 25	a4 6	6	T	4 20	4 41	p4 4
7	S	4 45	4 29	p4 3	10 22	11 02	a4 6	7	W	4 56	5 17	p4 4
8	M	5 22	5 06	p4 3	10 58	11 39	a4 5	8	T	5 33	5 54	p4 4
9	T	6 00	5 43	p4 2	11 35	12 13	a4 4	9	F	6 12	6 33	p4 3
10	W	6 42	6 21	p4 2	12 16	12 55	p4 4	10	S	6 50	7 11	p4 3
11	T	7 27	7 03	p4 1	12 55	1 37	p4 3	11	T	7 27	7 48	p4 3
12	F	8 18	7 50	p4 0	1 37	1 42	p4 3					
13	S	9 14	8 41	p3 4	2 23	2 28	p4 3					
14	S	10 15	9 38	p3 9								
15	M	11 19	10 40	p3 9								
16	T											
17	...											

Free Floaters Plankton Study

Purpose - The waters of the world, including lakes, harbors, bays and seas contain a huge assemblage of animals and plants which are in large measure at the whims of the currents and tides. Not all are microscopic although the majority are so small that you can swim through millions of these creatures and not know that you have. This group of organisms is the plankton.

To understand the basis of all sea life it is necessary to understand plankton. Composed of a range of sizes, from one celled diatoms and dinoflagellates to jellies with tentacles which can reach 20 or more feet in length, plankton are the link between the inorganic materials in the sea, solar energy and all other life on the planet. Even though many plankton can swim, their strength is limited so they are generally at the mercy of the motions of water in the sea.

By understanding plankton we get a better appreciation of the complex food webs of the sea, of the importance of larval stages for the distribution of both vertebrates and invertebrates and the unique and fascinating connections between some of the smallest creatures on earth, the phytoplankton, and the largest ever to live, whales. An understanding of plankton gives us an ability to monitor productivity in the sea and to predict the harvest which the sea will produce in the future.

Key Points -

- plankton are the basis of the food webs in the waters of the world.
- plankton come in many abilities, such as swimming strength and varieties and , including the larval stages of many animals.
- plankton includes many species of animals and plants and other microscopic organisms

Objectives -

- To collect and, where possible, identify plankton.
- To develop skills in collecting and handling planktonic organisms.
- To determine the concentration/numbers of plankton in an area.

Skill Development - Use of a plankton (neuston) tow net. Use of a microscope. Preservation of specimens (optional).

Connections - Researchers know that planktonic productivity in the sea is a prime determinant in the productivity of fisheries and the lives of marine animals. Research on plankton productivity at the University of Massachusetts Dartmouth, the University of Rhode Island and Woods Hole Oceanographic Institution has been illuminating trends and total productivity in Buzzards Bay and other regions for a number of years. From these studies, both the number and type of plankton in the region are well studied. Primary productivity, the measure of how much conversion of inorganic material and solar energy becomes living tissue, thanks to the efforts of phytoplankton, has been determined.

This information is critical to our understanding of the biosphere. Phytoplankton capture a large percentage of the sunlight which becomes living material on the planet. As a byproduct they produce net oxygen which then recharges the atmosphere. In addition, zooplankton feed on the phytoplankton creating the base of the ocean food web.

Periods of large planktonic growth are called blooms. When phytoplankton blooms, especially the dinoflagellates *Gymnodinium* and *Gonyaulax*, it causes red tide which can lead to paralytic shellfish poisoning of people.

There is mounting evidence that decreases in the thickness and density of the ozone layer over the earth is allowing additional ultraviolet radiation to strike the planet. One effect of that increase in radiation may be a global decrease in the productivity and numbers of plankton, especially phytoplankton.

Materials -

- neuston or plankton tow and tow line
- microscope (compound or dissecting)
- well slides
- preservative (Biosafe/alcohol)
- eye dropper or pipette
- plastic ruler
- petri or other shallow dish
- sample bottle

Station Logistics and Safety - Two to three students can work at a time in the handling of the tow off the stern or rear quarter of the ship. Care should be taken in lowering and raising the tow to prevent falling overboard or to scraping the hull with the net and catch bucket.

Getting Started - Ask the students what they ate today and what they are breathing. Many will name plants, some will name animals. Ask them where the animals and plants in the sea get their food. Ask them where they, as children get their air.

Procedures - Different nets have different size openings so no one net will capture all sizes or different types of plankton. The finer the mesh the more likely phytoplankton will be collected but these need to be towed more slowly than larger meshed nets to prevent damage. Moving slowly may mean that faster swimming zooplankton are able to avoid the net. As zooplankton are easier to see under a student or dissecting microscope, the sample collected will be with one of these larger mesh nets.

1. Construct the net assembly with catch bucket, net, open ring bridle and tow line securely attached together.
2. Secure the line of the net to a cleat in the rear quarter or stern of the boat.
3. Slowly lower the net into the water and let the line play out unimpeded, but maintain a light tension on the line to keep the net floating in sight and close to the surface. Let all the line play out and beginning timing the length of the sampling. Note the speed at which the boat is moving.
4. After 5 -10 minutes (more on longer expeditions), haul the assembly back to the boat (note the end time of the sampling) making sure that the catch bucket is hanging down allowing water to flow through and around it but not letting the sample spill out.
5. Pour the contents of the catch bucket into a sample bottle.
6. Below decks, use an eyedropper or pipette to extract a sample of the plankton captured. Examine under a microscope to determine number and kinds of plankton discovered. Move rapidly because plankton do not live long through the changes in oxygen levels and temperature which go with being under a microscope.
7. Using keys and guides, identify as many plankton as time allows.
8. (Optional - Save a sample of the plankton for later study by preserving a concentrated sample in biosafe.)

9. (Optional - Determine the volume of water which was sampled using the following rough calculation: $\text{volume of water} = 3.14 \times \text{radius of net opening} \times \text{distance towed}$ $V = 3.14 \times r^2 \times D$)

Findings and Observations - Record the time, location and any other environmental conditions at the time that the plankton sample is collected. Record the location, temperature, and depth of the water (from other tasks). After examining the sample, record the type, approximate numbers, density and distribution of plankton found.

Data can be recorded in a variety of manners based on the type of cruise or program. Vertical data (plankton at depth) can be determined by attaching a weight to the line of the tow and allowing the tow to settle to depth before collecting. This second collection gives an additional dimensional image of plankton distribution. Samples can also be taken over the length of a voyage, at certain times of day, or at specific targeted locations during the voyage.

Alternatively samples can be collected by using a hand pump operated from the deck. Suspend the net over the side of the ship, pump water by hand from the sea through the net, modeled after the how the net would function on a tow. Although the sample will not be as complete, this procedure allows for plankton collections dock side or when the ship is at anchor.

Discussion Questions -

1. Record the time, distance and then calculate the volume of water sampled.
2. Identify as many plankton species as time allows.
3. What factors may have affected the collection of plankton in this sample?
4. What are the most numerous specimens within the plankton sample? Why?
5. What was the role of the mesh size in determining which plankton were collected?
6. What would happen to the ecosystem of the sea if phytoplankton numbers decline?
7. What would happen to the ecosystem of the sea if the numbers of phytoplankton dramatically rise in an area?

Estimated Time on Task - 15 - 25 minutes

Links to Other Activities - The SECCHI Disc (Sediments, Sunlight and SECCHI Disks) and Forel Ule Scale (What Colors Am I?) tasks both relate to the materials, including plankton, which are floating in the sea. Nitrogen (Too Much Fertilizer?) and dissolved oxygen (A Breath of Air?) tasks relate nutrients and levels of oxygen in the water to organisms present.

Links to Curriculum Frameworks -

K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools.

5 - 8 - note and describe relevant details patterns and relationships; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 formulate testable questions and generate explanations using the results of predictions; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks - Students will be asked to make observations of the sea prior to collecting samples of plankton. On a superficial level there appears to be little life observable. Students will then be asked to predict what would happen if your concentrated that water and then observed what was in the concentrated sample. They also will be asked to decide what tools would be necessary to better investigate what they find in the sample.



Bacteria in the Waters (Pathogens)

Purpose -

By understanding the levels of bacteria (such as *E. coli*, the bacteria in the human intestinal system) in water, we can make connections between the actions of people both on land and at sea and the contamination of shellfish beds, fishing areas and swimming beaches. Of special importance are the levels of bacteria in our near shore areas, such as estuaries, salt ponds and harbors, all of which are areas where shellfish are found and often harvested.

Studying bacteria, using an indicator species such as *E. coli*, is a relatively safe and effective means for preventing disease causing viruses and bacteria (pathogens) from being consumed by people when they eat sea food or swim in the ocean. Understanding bacteria also gives us a better appreciation of the impacts of humans and other animals on the sea.

Key Points -

- human wastes and wastes from warm blooded animals can carry disease causing viruses and bacteria, some of which can survive in the sea.
- we can determine bacteria levels relatively easily but controlling our impacts on the amount of pathogens in water is a complex problem.
- most, but not all, additional pathogens in the marine environment are there due to the actions, directly or indirectly, of people.

Objectives -

- To determine the bacteria levels of water at locations throughout the expedition.
- To understand the implications of pathogens in water and how they play a role in how we manage the marine environment.

Skill Development -

- Use of collecting bottle to sample water at various depths and locations.
- Use of Membrane Filter kit and incubator to analyze indicator bacteria levels in water samples.

Materials -

- Collecting bottle for collecting at depth.
- Sterilized, sealable plastic bags.
- Small cooler and ice pack
- (At school/lab - Membrane Filter kits, incubator, hand lens, dissecting scope, chlorine bleach)

Station Logistics and Safety -

Two students can work together on this task and then should rotate so that two samples are taken . Care should be taken in lowering the collecting bottle over the side so as not to fall overboard nor to scrape the hull with the bottle. Use of the collecting bottle is relatively simple (see collecting bottle activity). Also care should be taken with the sterilized sample bags - do not open until time to fill with the sample. Label with a wax pencil or marking pen. Seal immediately and place in cooler with ice packs. Back at school all aseptic techniques should be adhered to insure safety of students. Disposal of incubated samples should include immersion in chlorine bleach. Students should thoroughly wash hands with an antiseptic soap after incubation and observation

Getting Started -

Ask students why and how they get diseases. Most will mention viruses (such as the common cold or flu). Few will know that bacteria and other pathogens cause disease. Ask them how is disease spread (sneezing, direct contact, things eaten, sexual activity). Tell them you are going to look for species of bacteria which can tell us whether pathogens are in the water.

Procedures -

1. Using a navigation chart determine the location of the ship relative to the shore, to rivers nearby, to the open ocean and to heavy development by people on shore.
2. Using a collecting bottle, collect a sample at the depth and location desired.
3. Label a sterilized sample bag. Pour at least 100 ml of the sample collected into the bag and seal immediately. Place the sample in the cooler and add an ice pack.
4. Repeat the procedure for each student and for different locations on the voyage.
5. Take the sample either to an on board lab or back to the classroom (in this case the cooler and ice pack should come from the school). Follow the directions on the Millipore kit for membrane filtering, for preparation of the sample for incubation in

the small petri disc provided and for incubation itself. Usually 24 - 48 hours at 35 degrees Celsius will allow for bacterial growth and then for analysis of results.

6. Dispose of the incubated sample by plunging in chlorine bleach.

Findings and Observations -

Your measurements will be in numbers of colonies of bacteria which grow per 100 ml of water sampled. Each colony will be a small, usually shiny, round area in the petri dish. Using a hand lens or dissecting scope back at the school count each of these areas and record the number of colonies per 100 ml of water.

What do the Findings Mean? -

E. coli, through what is called the coliform test, is the indicator species of bacteria of choice in testing waters for pathogens. *E. coli* is relatively safe to handle and will grow in an incubator in 24 - 48 hours when provided with nutrients and warmth comparable to that of the human body.

Standards are set for acceptable levels of bacteria in water samples based on this test. Exceeding the standards means that increasing numbers of people can or will get ill. The standards are:

Count of Colonies per 100ml of water	Management Action
0 - 13	no restrictions to shellfishing, fishing or swimming
14 or more	shellfishing prohibited
100 or more	fishing prohibited
200 or more	swimming prohibited

Discussion Questions -

1. Why is the amount of bacteria in water important for people to know and an important parameter in water quality monitoring?
2. Why does your sample have the bacteria levels you measured?
3. Where did all this bacteria come from in the first place?
4. What is the connection between your sampling location and the bacteria levels you found?

Connections -

The population in the coastal zone is presently 50% of the total population in most countries with a coast. More and more people mean more and more human wastes. In fact, estimates put the number of people in the coastal zone to double the present number within 35 years. Every one of those people eats and produces solid wastes. All of that

solid waste contains viruses and bacteria some of which are pathogenic, that is, disease causing. As more and more areas in watersheds are developed, for homes, schools and other areas where people concentrate, water runs off the land and to the sea. The growth of population in our coastal areas, and along rivers, has led to increased pathogens entering into coastal waters. Key areas where pathogens are concerns are outfalls from waste water treatment plants, areas where road run-off carries animal wastes, areas where farm wastes, such as manure, can enter into the waters, areas near waterways where septic systems are old or failing and areas where recreational boating is prevalent. Each of these areas are major sources of bacterial contamination.

People are not the only source. Birds and other warm blooded animals also contribute bacteria which show up in the coliform test. Large numbers of geese or swans, cows on farms too near streams and rivers, and dog and cat wastes on roads, all contribute to heightened bacteria levels in our waters.

Controlling all these sources of point and non-point pollution is a major effort being undertaken by local, state and federal agencies. Testing areas for bacteria is one of the most common monitoring efforts.

Tens of thousands of acres of shellfish beds and many miles of beaches are closed every year and, at times, permanently due to bacterial contamination. These closures cost the economy of Massachusetts tens of millions of dollars every year. Illegal harvesting of shellfish in contaminated areas has caused hundreds of cases of gastroenteritis (at least those reported) throughout the region and in places where shellfish are shipped.

Only recently has the trend shifted to opening these areas due to careful control of wastes entering the marine environment. Beaches and shellfish beds from Newburyport to Buzzards Bay have been reopened and contributing to the economy and recreational opportunities of Massachusetts residents and visitors.

Thanks to improved waste water treatment facilities (such as in Boston and New Bedford) and to actions on recreational boating providing pump out stations for wastes from boats), a hunt on geese which live year round in our area (all of which are non-native but were originally released from captivity), and improved septic system and farm

management practices, the situation is improving. People can now swim in Boston Harbor, once call the most polluted harbor in the country.

Links to Other Activities -

Bacteria levels can be compared to the findings from the Shoreline Survey activities, and the Dissolved Oxygen and Nutrients activities. In combination these four tasks can be used to determine potential human health treats and environmental health of the area under study. These activities should provide a basis for discussions of how what we do on the land and at play affects what happens in the water and what use we can make of our waters.

Estimated Time on Task - 5 - 10 minutes for collecting water

Links to Curriculum Frameworks -

K - 4 - NOT RECOMMENDED

5 - 8 - PROVISIONALLY RECOMMENDED IF SCHOOL HAS FACILITIES, TRAINED TEACHERS AND EQUIPMENT
note and describe relevant detailed patterns and relationships; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; analyze functional relationships to explain how a change in one quantity results in a change of another; use tables and graphs to interpret expressions, equations and inequalities; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks -

Students will be asked to predict the general levels (not specific numbers) of bacteria in sea water at various locations based on observations of water quality and land use. The students can pose questions to be answered such as “will water at one location be more contaminated than at another and why?”, “where does bacterial contamination in this region originate?” or similar questions which they might answer from their observations.

Floating Plants - Macroalgae

Purpose -

The waters of the world, including lakes, harbors, bays and seas contain a huge assemblage of animals and plants which are in large measure at the whims of the currents and tides. Not all are microscopic although the majority are so small that you can swim through millions of these creatures and not know that you have. Some of the plants, the macroalgae in the ocean, can reach tremendous sizes and yet can float from place to place. Many of the plants which inhabit these areas spend a part of their lives attached to rocks or other sediments. A small group of these larger plants spend no part of their lives attached to a substrate. Sargassum, which inhabits large areas of the central Atlantic, is one such species which becomes the home for many oceanic wanderers. Sargassum can be found throughout the Atlantic Ocean, carrying invertebrates along with it and becoming shelter for fish seeking cover.

By understanding macroalgae we can get a better appreciation of the complex food webs of the sea and of the importance and distribution of plants, vertebrates and invertebrates on the open seas. Life on a floating algae can be a model for the more involved food webs in the ocean.

Key Points -

- plants are the basis of the food webs in the waters of the world.
- floating plants are home to many organisms and play a role in the distribution of invertebrates.
- floating plants have special adaptations to life adrift on the sea.

Objectives -

- To collect and, where possible, identify floating plants.
- To develop skills in collecting and handling plants and small organisms.

Skill Development -

- Use of a plankton (neuston) tow net.
- Use of a hand lens.
- Preservation of specimens (optional).

Materials -

- neuston or plankton tow and tow line
- microscope (dissecting)
- hand lenses
- petri or other shallow dish
- examination tray or bucket
- plant press

Station Logistics and Safety -

Two to three students can work at a time in the handling of the tow off the stern or rear quarter of the ship. Care should be taken in lowering and raising the tow to prevent falling overboard or to scraping the hull with the net and catch bucket. Keeping the net as close to the surface as possible is critical to collecting floating plants.

Getting Started -

Ask the students how their families came to the United States. Most will tell you on ships of varying sizes. Ask them how animals and plants get to islands and from continent to continent. Have them conjecture as to what the means for transport may be. Then point to the floating mats of algae on the water and begin the activity.

Procedures -

Keeping the net at the surface may require adjusting the speed of the boat although a float on the top of the net may help. Begin this activity when floating macroalgae are found on the surface as you travel. This activity can also be done at rest so long as a current is moving past the boat.

1. Construct the net assembly with catch bucket, net, open ring bridle and tow line securely attached together.
2. Secure the line of the net to a cleat in the rear quarter or stern of the boat.
3. Slowly lower the net into the water and let the line play out unimpeded, but maintain a light tension on the line to keep the net floating in sight and at the surface.
4. Let all the line play out and beginning timing the length of the sampling. Note the speed at which the boat is moving.
5. After 5 -10 minutes (more on longer expeditions), haul the assembly back to the boat making sure that the catch bucket is the hanging down allowing water to flow through and around it but not letting the sample spill out. If you have traveled through a large mat of algae this procedure may take only a minute or two to fill the net.

6. Pour the contents of the net into an examination tray or bucket.
7. Examine samples of the algae and use a field guide to determine the type of algae caught. Under a dissecting microscope or with a hand lens to determine number and kinds of organisms discovered.
8. Using keys and guides, identify as many organisms as time allows.

(Optional - Save a sample of the algae for later study by preserving with a plant press. A plant press can be constructed out of 2 12"x12" pieces of plywood between which are stacked layers of newspaper and around which straps are placed to tighten the press. Label the paper first with pencil. Place the algae carefully on specimen paper by floating the algae in the examination tray and sliding the paper under the specimen. Spread out the sample. cover with newspaper and place in the press. Replace the newspaper every day until the algae is completely dry. Preserve by covering with a large, clear plastic bag or clear plastic wrap.)

Findings and Observations -

Record the time, location and any other environmental conditions at the time that the macroalgae is collected. After examining the sample, record the type, approximate numbers, density and distribution of algae and organisms found.

Data can be recorded in a variety of manners based on the type of cruise or program. Approximate area of ocean covered versus approximate area covered with floating plants, can be estimated. Locations of algae mats and of floating specimens can be plotted. Samples can also be taken over the length of a voyage, at certain times of day, or at specific targeted locations during the voyage. Randomizing the sampling will allow for discussion of why these organisms are found where they are.

Discussion Questions -

1. What is the importance of floating plants, based on the observations made in this collection process?
2. What factors may have affected the numbers and kinds of plants in this sample?
3. What are the most numerous specimens which live on the macroalgae sample? Why?
4. What would happen to the ecosystem of the sea if there were no macroalgae floating from place to place?

What do the Findings Mean?

The types and amount of macroalgae are indicative of the number and strength of coastal storms and the storms which carry Sargassum in from the open ocean. By analyzing the species of macroalgae we have a better understanding of currents and distribution of organisms in the sea. Codium, however, tells a slightly different story, however. This algae, with finger like projections which float, rather than specific floats on stems, came to North America either attached to the hulls of ships from Asia or in bilge water pumped into the ocean from those ships. As a non-native species on which few marine animals feed, Codium has spread rapidly in southern New England. Often favoring shellfish as its hard substrate, Codium is sometimes called oyster killer, as it grows on shells of live oysters and floats away carrying the oyster from its preferred habitat. Dead eel grass can be an indication of storms and boat damage to the benthos or can be an indication of wasting disease, a reoccurring disease which in the 1930's and today is killing off large areas of this important species. Eel grass is the preferred habitat for young scallops, food for geese and ducks and the haunts of young fish as they grow.

Connections -

The basis for the ocean food web is the phytoplankton which move with ocean currents. Also of importance are the attached and floating plants which include macroalgae (kelp, rockweeds, Codium, Sargassum) and true flowering plants (such as eel grass). Requiring a hard substrate to grow, many macroalgae become floating plants after storms tear whole or parts of these organisms from rocky shores, from attachments to the shells of mollusks and other shellfish, and man-made structures such as pilings or breakwaters.

These plants have adaptations for floating. Most have actual floats, bulbous expansions of the algal stems, filled with liquid or gases making the plant less dense than the water in which the plants float. When detached from the substrate these algae are at the whim of tides and currents, and carry with them the invertebrates (crabs, mussels, barnacles, snails, and other animals) which call these plants home.

Sargassum is unique in that it does not have an attached stage in its life cycle. Most of the Sargassum is located in an area of open ocean to the east and south of Bermuda and extending for many miles in all directions. Species of animals have adapted to life in, on or under these floating

plants, among them specially adapted crabs and other invertebrates. Interestingly, fresh water eels from Europe and North America travel to the Sargassum to breed and have their young which then migrate back to the original river or stream from which their parents came.

Estimated Time on Task - 20 - 25 minutes

Links to Other Activities -

The Birds activity (Over and Under the Waves) relates to this activity as the mats of macroalgae become the resting locations for some birds, especially in migration, and a source of food.

Links to Curriculum Frameworks -

K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools.

5 - 8 - note and describe relevant details patterns and relationships; analyze alternative explanations and procedures.

9 - 10 formulate testable questions and generate explanations using the results of predictions; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks -

Students will be asked to make observations of the sea prior to collecting samples of macroalgae. On a superficial level there appears to be little life observable. Students will then be asked to predict what would happen if you sampled for a long period of time. They also will be asked to decide what tools would be necessary to better investigate what floats on the ocean.



Tiny Fish - Minnows and the Food web

Purpose - By understanding the number and kinds of small animals, including fish, crabs, and shrimp, which inhabit our coastal waters we can begin to build a **food web** of our region. We can also understand how energy and materials move from the sun to plants, from plants to animals and from small herbivores or detritivores to larger predators (carnivores)

Key Points -

- animals have evolved to live in either salt or fresh water with some exceptions which can move from one to another.
- some animals (certain fish, crabs and shrimp) are the connection between the energy of the sun which is caught by plants, and the rest of the ocean **food web**.
- some animals feed on dead and decomposing plants and animals, helping cycle materials through the marine environment.
- some fish, crabs and shrimp are attracted to bait, such as dead fish, squid or crabs, placed in a minnow trap.

Objectives -

- To capture and identify small animals at various depths and locations throughout the expedition.
- To understand the relationship between **abiotic** factors and the distribution and number of small animals in the marine environment.

Skill Development - Use of minnow trap at various depths and locations.

Materials -

- Minnow trap and marked line for collecting at depth.
- Bait for the trap - clam necks, fish parts, squid.
- Bucket or clear plastic "tank" with sea water collected on site.
- Fish identification guides (Peterson Guide to Atlantic Fishes, fish identification card)
- Invertebrate identification guides (Peterson Guide to the Atlantic Seashore, National Audubon Guide to Atlantic Seashore Creatures)
- Ice packs, fish tank pump, air stone and hoses (if animals are to be collected and kept for more than 15 minutes)

Station Logistics and Safety -

Begin this task as soon as the ship stops at a sampling site. The number and diversity of animals varies greatly from place to place. Time of day and sampling duration are important considerations. **Tides** also affect results. For best results sample at a high **tide** and for as long as possible (overnight is best, if possible). Two students can work together on this task. Care should be taken in lowering the minnow trap over the side so as not to fall overboard nor to scrape the hull with the trap. Use of the minnow trap is relatively simple but time must be allowed for the trap to settle at its location (including depth) and to attract animals to the bait.

Getting Started -

- Ask students what lives in the seas in their area.
- Ask them if any of them or any of their parents fish.
- Ask them what they use for bait. Many may have used bait fish or clam necks, worms or squid. Show them the bait and the trap they will use.
- Ask them to predict what they will catch with this bait/trap combination.

Procedures -

1. Using a navigation chart determine the location of the ship and the type of bottom where the sampling will take place. Determine the location of the ship relative to the shore, to rivers nearby and to the open ocean. Using the fathometer, determine the depth in the area.
2. The minnow trap is in two parts and has a line attached to it. Place bait in one half of the trap and connect the two halves together. Make sure the line is securely attached to the trap.
3. Securely attach the loose end of the line to a cleat or other point on the ship. Slowly lower the minnow trap to the depth you wish to sample. Record the depth at which the sampling will take place and the time when the sampling began.
4. After as long a time as possible, but not to exceed 8 hours, pull the trap from the water and open the trap over a bucket or portable fish tank. The water in the bucket should be taken from the location and depth (if possible with the collecting bottle) at which the trap was left for sampling.
5. If time and traps allow, resample at different depths with separate traps. Simultaneous sampling at different depths is desirable.
6. Using field guides, identify the **species** of animals collected and the number of each **species**. Record this information.
7. If the animals are to be kept for more than 15 minutes, add an ice pack to the bucket or portable fish tank. If the animals are to be

kept for an extended period of time, run an aquarium pump (attached via small hoses to an air stone in the water) to aerate the water. Change 25% of the water every 4 hours if water of similar temperature and salinity is available.

8. Clean the trap with sea water and dispose of the excess bait the excess bait can be thrown overboard; one of the rare instances when this behavior is allowable!).

Findings and Observations - Below is a list and description of some of the animals which you are likely to find in a minnow trap in this region. Other animals are possible, including, but not limited to octopus(!), other crabs, small lobsters and the young of other fish species.

- Mummichogs (*Fundulus heteroclitus*) - to 6 inches (15cm); in marshes and tidal creeks; very hardy and common in estuaries;
- Striped Killifish (*Fundulus majalis*) - to 7 inches (18cm); vertical stripes on sides; hardy and known to be able to flop towards water when stranded on land.
- Cunner (*Tautoglabrus adspersus*) - to 18 inches (45cm); variable in color with dorsal (top) fin extending from just behind gills to just before tail; alters color to match bottom.
- American Eel (*Anquilla rostrata*) - to 5 feet (1.5m) but rarely over 3 feet (90cm); females larger than males; green above and sometimes yellow below; adults enter sea in winter and early spring; young swim from Sargasso Sea back to river from which parents came.
- Four Spine Stickleback (*Apeltes quadracus*) - to 2.5 inches (6.25 cm); spines on dorsal (top) side; nests in estuaries (male changes color to bright red on ventral (belly) side to attract female to nest - after egg laying and fertilization male drives female away and cares for eggs.
- Green Crabs (*Carcinus maenas*) - to 5 inches across (13cm); can switch to air breathing when out of water; hardy and adaptable to varying salt and temperature environments; not native to North America - probably hitched a ride on ship hull; large, long claws.
- Spider Crabs (*Libinia emarginata*) - to 4 inches across (10cm); inhabits soft bottoms; small claws for picking up or ripping dead material; sometimes have algae or sponges growing on short spines of carapace (top shell) hence grouped with other decorator crabs.
- Sand Shrimp (*Crangon septemspinosa*) - to 2 inches (6cm); important prey for many small fish and other animals in estuaries; nearly the color of sand (with speckles) so hard to see on sandy bottom; feeds on plankton and larvae and detritus from decaying plant material.
- Shore Shrimp (*Palaemonetes vulgaris*) - to 2 inches (6cm); nearly clear; important prey for many small fish and other animals in estuaries; feeds on plankton and larvae and detritus from decaying plant material.

What do the Findings Mean? -

Fish and invertebrates in this region can be indicators of a variety of environmental factors. Too little dissolved oxygen and the fish and invertebrates listed above begin to disappear. Some will be replaced by other animals, such as worms, but others will not have ecological replacements. Most of these animals are eaten by birds, lobsters, and other fish. Compare the animals found to the location of the ship relative to shore, to the salinity and dissolved oxygen levels at the depth where the animals are found, and to the plankton and other food in the water. Also, the number and diversity of animals caught can be a reflection of the time of day, duration and depth of sampling.

Discussion Questions -

1. Why did you find the animals you caught in the location where you caught them?
2. How were your animals distributed in the water column (vertically) or from location to location (horizontally)?
3. What environmental conditions must your animals be adapted to in order to survive?
4. What is the connection between your sampling location, the abiotic factors (salinity, temperature, dissolved oxygen levels) and the animals you found?

Connections -

Minnows, the general name for small fish caught along the shore, small shrimp and crabs provide the transition from the plants to larger predatory fish. The predatory fish include cod, haddock flounder, bluefish and striped bass, all of which are important commercially. As water quality in near shore areas declined in the past, so too did the number and diversity of near shore residents. One effect of this change may have been a decline in the number and variety of fish caught offshore. Although overfishing may be the main culprit in fisheries decline, breaking the food chain from small animals to larger ones may have played a role. As much as 70% of all commercially important fish depend on the near shore areas, such as saltmarshes, with their abundance of prey species, for survival.

Links to Other Activities -

Animals caught can be compared to the findings from the salinity (Salty Seas) and dissolved oxygen (Breathing Water) tasks. Different collecting techniques can be compared such as crab traps (Nasty, Nasty Claws) and

plankton tows (Free Floaters). Navigation exercises and locating the sampling stations relative to fresh water inflows will demonstrate the connections between marine and fresh water systems and the animals that live there. Locating salt marshes will help clarify why some species are caught and others are less common.

Estimated Time on Task - 15 - 30 minutes up to 8 hours

Links to Curriculum Frameworks -

K - 4 - Planning and conducting a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; analyze functional relationships to explain how a change in one quantity results in a change of another; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks -

Students will be asked to predict what animals they may find on the bottom or at varying depths based on their location. The students can pose questions to be answered such as “what animals are here and why”, “will there be more animals in the estuary than on the open seas” or similar questions which they might answer from their observations.

Nasty, Nasty Claws - Crabs and the Food web

Purpose -

By understanding the number and kinds of small animals, including fish, crabs, and shrimp, which inhabit our coastal waters we can begin to build a **food web** of our region. We can also understand how energy and materials move from the sun to plants, from plants to animals and from small herbivores or detritivores to larger predators (carnivores).

Key Points -

- crabs are well adapted to life on the bottom of the sea thanks to their claws, ability to move and actively pursue prey or find vegetation.
- some animals (certain fish, crabs and shrimp) are the connection between the energy of the sun which is caught by plants, and the ocean **food web**.
- some animals feed on dead and decomposing plants and animals, helping to cycle materials through the marine environment.
- some fish, crabs and shrimp are attracted to bait, such as
- dead fish, squid, clam necks or chicken parts, in a crab trap.

Objectives -

- To capture and identify crabs at various locations throughout the expedition.
- To understand the relationship between **abiotic** factors and the distribution and number of crabs in the marine environment.

Skill Development -

- Use of crab traps at various locations.
- Recording data.

Materials -

- Crab trap and marked line for collecting at depth.
- Bait for the trap - clam necks, fish parts, squid, chicken parts.
- Bucket or clear plastic "tank" with sea water collected on site.
- Invertebrate identification guides (Peterson A Field Guide to the Atlantic Seashore, Audubon Guide to North American Seashore Creatures)
- Ice packs, fish tank pump, air stone and hoses (if animals are to be collected and kept for more than 15 minutes)

Station Logistics and Safety -

Begin this task as soon as the ship stops at a sampling site. The number and diversity of animals varies greatly from place to place. Time of day and sampling duration are important considerations. **Tides** also affect results. For best results sample at a high **tide** and for as long as possible (overnight is best, if possible) Four students can work together on this task. Care should be taken in lowering the crab trap over the side so as neither to fall overboard nor to scrape the hull with the trap. Use of the crab trap is relatively simple but time must be allowed for the trap to settle at its location (including depth) and to attract animals to the bait.

CRABS CAN PINCH AND HURT. Hold all crabs from the sides of the upper carapace. Some crabs, such as blue crabs, can reach around with their main claws and can hurt when they pinch. Exercise care in the holding and moving of these animals.

Getting Started -

Ask students what animals walk on the ocean floor some of which are good to eat. Many will say lobsters. Others may say crabs. Ask them what they would use for bait to catch crabs. Show them the bait and the trap they will use. Have them guess which kind of bait will be most effective in catching crabs.

Procedures -

1. Using a navigation chart determine the location of the ship and the type of bottom where the sampling will take place. Determine the location of the ship relative to the shore, to rivers nearby and to the open ocean. Using the fathometer, determine the depth in the area.
2. The crab trap is simple to use. A line is attached to the trap allowing you to lower it to the bottom (or to any depth - with crab traps you want to bait and fish the bottom. Place bait in the center of the trap. Make sure the line is securely attached to the trap.
3. Securely attach the loose end of the line to a cleat or other point on the ship. Slowly lower the trap to the bottom where you wish to sample. Record the depth at which the sampling will take place and the time when the sampling began.
4. After as long a time as possible, but not to exceed 8 hours, pull the trap from the water. Each crab will need to be removed and placed in a bucket or portable fish tank. The water in the bucket should be taken from the location and depth (if possible with the collecting bottle) at which the trap was left for sampling.

5. If time and traps allow, resample at different locations with separate traps. Simultaneous sampling at different areas is desirable.
6. Using field guides, identify the species of animals collected and the number of each species. Record this information.
7. If the animals are to be kept for more than 15 minutes, add an ice pack to the bucket or portable fish tank. If the animals are to be kept for an extended period of time, run an aquarium pump (attached via small hoses to an air stone in the water) to aerate the water. Change 25% of the water every 4 hours if water of similar temperature and salinity is available. If the animals are not to be kept return them to the water within 15 minutes.
8. Clean the trap with sea water and dispose of the excess bait (the excess bait can be thrown overboard; one of the rare instances when this behavior is allowable!).

Findings and Observations -

Below is a list and description of some of the animals which you are likely to find in a crab trap in this region. Other animals are possible, including, but not limited to octopus(!), other crabs, small lobsters and some bottom feeding fish species.

- Green Crab (*Carcinus maenas*) - to 5 inches across (13cm); can switch to air breathing when out of water; hardy and adaptable to varying salt and temperature environments; not native to North America - probably hitched a ride on ship hull; large, long claws.
- Spider Crab (*Libinia emarginata*) - to 4 inches across (10cm); inhabits soft bottoms; small claws for picking up or ripping dead material; sometimes have algae or sponges growing on short spines of carapace (top shell) hence grouped with other decorator crabs.
- Hermit Crab (*Pagurus sp.*) - at least two species inhabit our region (long clawed and flat clawed varieties); feed on dead and decaying material, including animal and plant material; use the shells of periwinkles, dog whelks, oyster drills and other snails for protection of exposed tail region.
- Blue Crab (*Callinectes sapidus*) - to 9 inches (22.5cm) wide; active swimming predatory crab; important commercially south to Chesapeake Bay; can deliver a nasty pinch. Handle with care.
- Rock Crab (*Cancer irroratus*) - to 5 1/2 inches (13cm) wide: very common crab of the intertidal zone and shallow waters; can pinch but usually are not as aggressive as blue or lady crabs. Sometimes called Jonah crab.
- Lady Crab (*Ovalipes ocellatus*) - to 3 inches (8cm): aggressive swimming crab which buries itself in bottom to await prey; can deliver a nasty pinch. Handle with care.

What do the Findings Mean? -

Invertebrates in this region can be indicators of a variety of environmental factors. Too little **dissolved oxygen** and the invertebrates listed above begin to disappear. Some will be replaced by other animals, such as worms, but others will not have ecological replacements. Most of these animals are eaten by birds, lobsters, and other fish.

Compare the animals found to the location of the ship relative to shore, to the **salinity** and **dissolved oxygen** levels at the depth where the animals are found, and to the **plankton** and other food in the water. Also, the number and diversity of animals caught can be a reflection of the time of day, duration and depth of sampling and the bait used.

Discussion Questions -

1. Why did you find the animals you caught in the location where you caught them?
2. How were your animals distributed from location to location?
3. What environmental conditions must your animals be adapted to in order to survive?
4. What is the connection between your sampling location, the **abiotic** factors (**salinity**, temperature, **dissolved oxygen** levels) and the animals you found?
5. What do the different shaped claws tell you about how and what the crabs you caught eat?

Connections -

- Crabs, in their many sizes and adaptations to the marine provide an excellent example of how form follows function. Each crab **species** has a claw shape designed around the feeding behavior of that **species**. Large swimming crabs, such as blue crabs, have large, sharp cutting claws, while spider crabs, which scavenge rather than hunt, have small claws good for tearing at dead and decomposing material.
- Crabs are important economically, more so in the Chesapeake Bay area than in New England. Soft shell, or molted, blue crabs annually generate between \$20 - \$80 million in revenue for crabbers.

Links to Other Activities -

Animals caught can be compared to the findings from the **salinity** (Salty Seas) and **dissolved oxygen** (Breathing Water) tasks. Different collecting techniques can be compared such as minnow traps (Tiny Fish) and **plankton** tows (Free Floaters). Navigation exercises and locating the

sampling stations relative to fresh water inflows will demonstrate the connections between marine and fresh water systems and the animals that live there. Locating salt marshes, rocky shores or bottom type will help clarify why some species are caught and others are less common in the samples.

Estimated Time on Task - 15 - 30 minutes up to 8 hours

Links to Curriculum Frameworks -

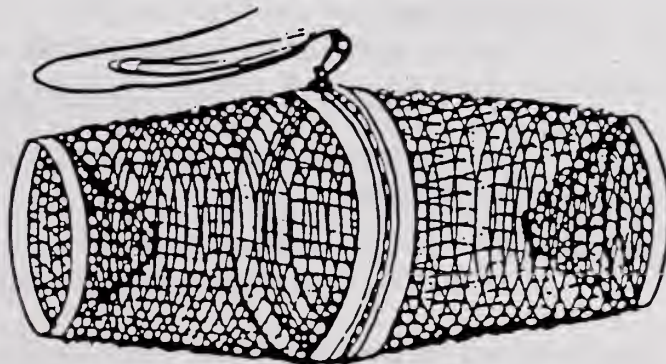
K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant detail patterns and relationships; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; analyze functional relationships to explain how a change in one quantity results in a change of another; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks -

Students will be asked to predict what animals they may find on the bottom or on bottoms with different substrates (sand, soft mud rock or hard bottom). The students can pose questions to be answered such as "what animals are here and why", "will there be more crabs on a rocky or hard bottom than in the estuary or on the open seas" or similar questions which they might answer from their observations.



Marine Mammals

Purpose -

The waters of the world are home to marine mammals which have remarkable adaptations to life in the sea. By definition, marine mammals include more than whales, dolphins and porpoises. The group includes seals, sea lions, polar bears, sea otters and manatees as well. This diverse group is all afforded protection by the Marine Mammal Protection Act. Although protected by the same law, the adaptations to life in the sea for each of these types of animals varies greatly. In New England waters the two marine mammals groups most commonly observed are the cetacea (whales, dolphins and porpoises and the pinnipeds (seals). The seas and coasts of New England are special because large concentrations of these animals can be seen relatively close to shore at all seasons of the year.

To understand the relationship between marine mammals and all other sea life it is necessary to observe their movements and behaviors, especially how and on what they feed. By contrast with birds, however, observing marine mammals can be very difficult. The amount of time they stay underwater, or in the case of seals their tendency to slip off rocks and into the water when a boat approaches, can make detailed observations a challenge.

Key Points -

- many species of marine mammals have adapted to life in the sea and by observing them we can often tell what is happening to the food chain in the ocean.
- marine mammals are endowed with many abilities, such as swimming strength, diving to great depths while holding their breath, feeding style, size, shape, size of groupings and migrations, and that intangible "intelligence"

Objectives -

- To observe and, where possible, identify marine mammals
- To develop skills in using field guides and binoculars.
- To determine the concentration/numbers of marine mammals in an area.

Skill Development -

- Use of binoculars.
- Use of field guides.

Materials -

- binoculars
- A Field Guide to Whales, Dolphins and Porpoises marine mammal review card

Station Logistics and Safety -

Two students can work at a time in the identification of marine mammals sighted and the behaviors of those animals. Care should be taken in use of binoculars. The neck strap should be worn at all times. The students should spot for each other on the deck while observing marine mammals, in order to prevent falling or loss of balance while spotting individuals or groups.

Getting Started -

Ask the students how marine mammals survive in the water and what resources these animals might use from the sea. Ask them how best to tell what a marine mammal is doing, a task which will help them clarify the concept of "behavior" before they start making observations. Address the issue of brief views of marine mammals which most observers get due to the depths, and the lengths, to which whales dive. Have students hold their breath for as long as possible (and safe). This is usually less than a minute. Seals can hold their breath for as much as 20 minutes and whales for even longer! Also, ask students how they distinguish between each other. (clothes, appearance, hair, eye and skin color, etc.) Ask them how they might distinguish between individual marine mammals.

Procedures -

Different binoculars have different magnifications (the first number on the binoculars) and width of field (the second number). This may appear as 7x35, 7x50, 8.5x44, 10x50 or other combinations. Remember when using binoculars that the higher the magnification the harder it is to hold the binoculars steady on the deck of a rolling ship. The tradeoff with high magnification is seeing clearly both farther and in more detail. The wider the width of field, the more marine mammals which can be seen and identified.

1. The team of two students should review the card of marine mammals likely to be seen on or under the water. Don't expect to

memorize from the card, only get an idea of general body shape, colors and size.

2. Stand amidships and one student should scan the waters from the bow to the stern as far as can be clearly seen for identification purposes. As a marine mammals is sighted a record should be made of what was seen. The second should keep records and assist by finding species in the field guide or identification cards. Students should take turns doing the scanning and the recording.
3. As time allows, watch individual marine mammals to determine what behaviors they are demonstrating. Included in behaviors are resting, diving, rapid swimming, lob tailing, flipper flapping, hauling out, spy hopping or watching, feeding, or other behaviors which are observable.

(Optional - Pull a neuston or plankton tow through an area where whales have been feeding to determine what they might be using for food in this area. Make sure to do this after the whales have left: otherwise you would be breaking the law!)

Findings and Observations -

- Record the time, location and any other environmental conditions at the time that each marine mammal identification takes place.
- Record the species of marine mammals.
- Record the number of each species observed and their habits. Record the specific behaviors observed.

Data can be recorded in a variety of manners based on the type of cruise or program. Observations can be made on a regular, periodic basis along the route of a trip, once per habitat on a shorter trip, or just once when the ship is stopped on a short trip.

Observations can be combined back in the classroom and the species, number, distribution and behaviors discussed and plotted on maps of the region.

Discussion Questions -

Record the time and distance of the cruise and then calculate the population of each species in the area.

1. What factors may have affected the type, number, distribution and behaviors of marine mammals?
2. What are the most numerous species on this cruise? Why?
3. What was the role of the binocular magnification in identification and recording distribution?

4. What would happen to the ecosystem of the sea if marine mammals decline in numbers and types in the marine environment?
5. Why do people work so hard to preserve marine mammals, what is the mystique of these animals?

What do the Findings Mean?

Marine mammal populations have generally been increasing since the protection was afforded these animals. The data collected in this activity will only provide a glimpse into the complex world of these creatures. For cetacea, the numbers of humpback whales, for example, now numbers in the thousands as it does for fin whales. Minke whales number over one hundred thousand and there is a call by some historically whaling countries to reopen the hunt. For north Atlantic right whales, which once numbered over one hundred thousand, the population is slightly over 300 animals so seeing even three right whales is the equivalent of 1% of the entire population. For seals, however, the number trend is in the opposite direction. Harbor seals now number in the tens of thousands, with as many as 600 hauled out on Monomoy Island in winter and 300 - 400 estimated to use the islands near Cuttyhunk for winter haul outs. All along the coast of Massachusetts harbor seals, and to a lesser extent, gray and the arctic seal (harp and hooded), sightings have increased.

Connections -

Thanks to the protection of both the Marine Mammal Protection Act and the Endangered Species Act, most marine mammal species in New England are recovering from low points reached after whaling was stopped in this century. The one exception may be the critically endangered north Atlantic right whale, whose numbers have been relatively constant in the low 300's for more than a decade (determined thanks to the research of the New England Aquarium, the Center for Coastal Studies in Provincetown and many other contributors to the effort).

Humpback, right, fin, minke and pilot whales, Atlantic white-sided dolphins, and harbor porpoise all frequent the Massachusetts coast and nearby waters, with concentrations on Stellwagen Bank, Jefferies Ledge and Cape Cod Bay. Harbor seals concentrate along the shore mostly in the winter months, but are increasingly being seen year round. Hundreds can often be seen sunning themselves (called hauled out) on islands and rocky outcroppings of the shore. Other species of seals, such as the large gray seal, harp and hooded seals, are more arctic

in their choice of habitat but are apparently expanding their range. Gray seals haul out and have pups on the islands between Marthas Vineyard and Nantucket.

The recovery of these species speaks volumes for the value of protection and careful management. Cooperation between whale watch boats, the Coast Guard, commercial vessels, educators, researchers and wildlife managers has lead to heightened public awareness and understanding of marine mammal habitat needs. This information is critical to our protection of these animals. The largest whales filter small fish (sand lance and pollock) from the sea, with the exception of the right whale which feeds on copepods, a form of plankton. Toothed whales, such as dolphins and porpoise, also feed on fish and squid, as do many of the seals. Because this diet places marine mammals at the top of the food chain in many areas, there is concern that chemicals, such as pesticides, may be bioaccumulating in their tissues. Long term these materials may be a greater threat to marine mammals than any other human actions, including the limited hunting still occurring today.

Estimated Time on Task -

15 - 20 minutes depending on location of study this could easily double on a hot whale watching site.

Links to Other Activities -

- Tiny Fish (Minnows and the Food Web) will give an understanding to what marine mammals might be using as food as they feed.
- Free Floaters (Plankton Study) provides information on the smaller organisms which marine mammals may be using as food sources.

Links to Curriculum Frameworks -

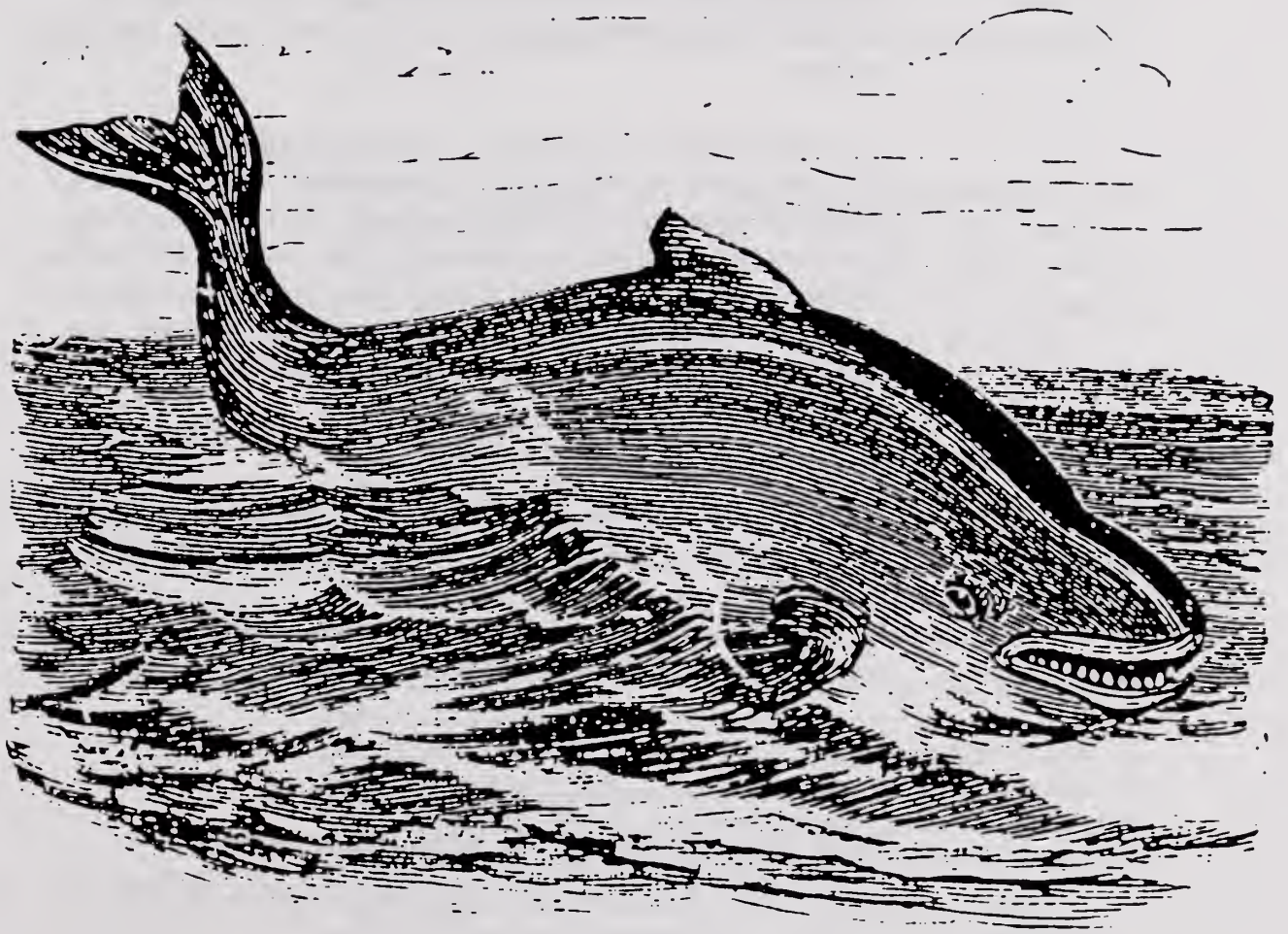
K - 4 - Planning and conducting a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions.

Application of Frameworks -

Students will be asked to make observations of the sea prior to making observations of marine mammals. At first glance, the types and numbers of marine mammals might seem difficult to determine. In fact most of the places observed will have little if any marine mammal populations. Students should predict where marine mammals might be found and why, and what the marine mammals will be doing at those locations.



Over and Under the Waters - Birds

Purpose -

The waters of the world are home to birds which have remarkable adaptations to life on, over and around the sea. Some species only travel over water, never feeding while at sea. Ospreys and peregrine falcons, for example, fly from New England to South America, rarely alighting the entire way. Other birds use the ocean's waters seasonally; they only come to the sea to feed in the winter, when fresh water lakes and rivers are frozen. Many ducks, including buffleheads and mergansers fit this description. Some birds are both land and sea creatures, such as gulls, which can be equally at home inland, at food sources such as dumps or farms, nesting on islands, or feeding while paddling on the surface. Among the most amazing birds, however, are the birds which can spend nearly all of their life at sea, only coming to land to nest and raise their young. This group includes shearwaters, petrels, gannets, and alcid, including puffins.

To understand the relationship between birds and all sea life it is necessary to observe their movements and behaviors, especially how and on what they feed. By understanding birds we get a better appreciation of the complex food webs of the sea, and the relationship of what happens in the sea to that on the land. Birds, such as canaries in mines, can be excellent indicators of environmental quality and loss of habitat.

Key Points -

- many species of birds have adapted to life in and around the sea and by observing them we can often tell what is happening underwater
- birds come with many abilities, such as swimming strength and feeding style, flight pattern and diving expertise

Objectives -

- To observe and, where possible, identify bird life.
- To develop skills in using field guides and binoculars.
- To determine the concentration/numbers of birds in an area.

Skill Development -

- Use of binoculars.
- Use of field guides.

Materials -

- binoculars
- A Field Guide to the Birds (Eastern Edition), Peterson Guide
- data sheet

Station Logistics and Safety -

Two students can work at a time in the identification of birds sighted and the behaviors of those birds. Care should be taken in use of binoculars. The neck strap should be worn at all times. The students should spot for each other on the deck while watching birds, in order to prevent falling or loss of balance while spotting individual birds or groups.

Getting Started -

Ask the students how birds might survive on the water and what resources birds might use from the sea. Ask them how best to tell what a bird is doing, a task which will help them clarify the concept of "behavior" before they start making observations.

Procedures -

Different binoculars have different magnifications (the first number on the binoculars) and width of field (the second number). This may appear as 7x35, 7x50, 8.5x44, 10x50 or other combinations. Remember when using binoculars that the higher the magnification the harder it is to hold the binoculars steady on the deck of a rolling ship. The tradeoff with high magnification is seeing clearly both farther and in more detail. The wider the width of field, the more birds which can be seen.

1. The team of two students should review the card of birds likely to be seen on or near the water. Don't expect to memorize from the card, only get an idea of general body shape and size.
2. Stand amidships and one student should scan the waters from the bow to the stern as far as can be clearly seen for identification purposes. As a bird is sighted a record should be made of what was seen. The second should keep records and assist by finding species in the field guide or identification cards. Students should take turns doing the scanning and the recording.
3. As time allows, watch individual birds to determine what behaviors they are demonstrating. Included in behaviors are resting, soaring, flap flying, feeding, diving, tipping up to feed, carrying nesting materials or other behaviors which are observable.

(Optional - Pull a neuston or plankton tow through an area where birds have been feeding to determine what they might be using for food in this area.)

Findings and Observations -

Record the time, location and any other environmental conditions at the time that the bird identification takes place. Record the types of birds (specific names are important but not necessary -a good description will allow for later identification). Record the number of each species observed and the habitats they are using. Record the specific behaviors observed.

Data can be recorded in a variety of manners based on the type of cruise or program. Observations can be made on a regular, periodic basis along the route of a trip, once per habitat on a shorter trip, or just once when the ship is stopped on a short trip. Observations can be combined back in the classroom and the type (species), number, distribution and behaviors discussed.

Discussion Questions -

Record the time and distance of the cruise and then calculate the population of each species in the area.

1. What factors may have affected the type, number, distribution and behaviors of birds?
2. What are the most numerous species on this cruise? Why?
3. What was the role of the binocular magnification in identification and recording distribution?
4. What would happen to the ecosystem of the sea if birds decline in numbers and types in the marine environment?
5. What would happen to the ecosystem of the sea if the numbers of birds dramatically rise in an area?

What do the Findings Mean?

Bird inventories are critical to our understanding of the biosphere. Birds form the top of the food chain in many areas, bioaccumulating chemicals, such as pesticides, in their tissues. Loss of bird life due to chemical contamination was one thrust of Rachel Carson's key environmental work, Silent Spring. Monitoring of bird species and populations tells us much about what is happening in the ecosystem in an area. Some species also are extending their ranges into our area, demonstrating that efforts at coastal clean up and protection may be working. By comparing data from pelagic and other on-water or shoreline surveys we can tell the

trends and tendencies in wildlife populations and try to help wherever possible.

Connections -

Birds play several roles in the coastal and marine environments. Shorebirds feed on the small invertebrates found on beaches making a connection between the shore and the sea. Long legged waders, such as egrets and herons, feed on the small fish, crabs, and shrimp which frequent salt marshes, creating a link to highly productive habitats. Geese and swans feed on eel grass and other submerged plants, with geese clipping the plants and swans ripping the plants up roots and all. Ospreys hunt from the sky plunging talons first into the estuary and near shore waters extracting fish.

Research by Manomet Observatory, Massachusetts Audubon, the Lloyd Center for Environmental Studies, among others, and state and federal agencies have demonstrated the importance of Massachusetts to bird life. Roseate terns, a federally listed endangered species, nests in one of its largest concentrations, on Bird Island off of Marion. Piping plovers, also federally-listed as endangered, depend on the beaches of the Commonwealth for nearly 20% of the nest sites in the eastern United States. Ospreys, at one time nearly lost to the coasts of New England, have recovered thanks in large measure to the reduction in the use of organochlorine pesticides (such as DDT) and to the efforts by private citizens and conservation groups to increase nesting sites along the estuaries and coasts.

Estimated Time on Task - 15 - 20 minutes

Links to Other Activities -

Tiny Fish (Minnows and the Food Web) will give an understanding to what the birds might be using as food as they feed along the shore or at sea. Free Floaters (Plankton Study) provides information on the smaller organisms which birds may be using as food sources. Moving Waters (Currents and Motion) may provide additional information on the connection between distribution of food sources and bird life.

Links to Curriculum Frameworks -

K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools;

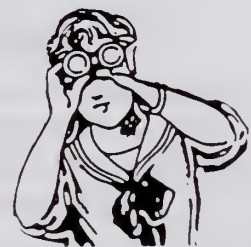
5 - 8 - Note and describe relevant details patterns and relationships; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions.

Application of Frameworks -

Students will be asked to make observations of the sea prior to making observations of bird life. At first glance, the types and numbers of birds might seem difficult to determine. In fact, there may appear to be little bird life observable.

Students will then be asked to predict what birds there are and why there are where they are found.



We're Watching You (Shoreline Survey)

Purpose - What happens in the waters of Massachusetts is dependent in part in what we do on the land adjacent to and flowing into our waters. An expedition on the Schooner ERNESTINA can only take us part way up rivers and estuaries and into the watersheds. As a result we cannot analyze what is happening up stream to effect water quality and the life in our waters.

What we can observe is what is happening along the shores we pass as we travel on our expedition. How many homes, industries, open or natural areas, marine related uses and similar uses of the shoreline are there? What are the possible impacts of those uses on the near shore waters?

Key Points -

- nearly 50% of the population lives and works within the coastal zone.
- by careful observation we can identify the uses of the shoreline by people .
- from our observations we can predict the impacts on water quality and living things in the water.

Objectives -

- To make careful observations of the shoreline in order to identify uses and possible impacts.
- To prepare a map or chart of the shoreline in order to plot the uses to which the shoreline is put.

Skill Development -

- Use of navigational chart to determine location and outline of shoreline.
- Use of binoculars to observe shoreline.

Materials -

- Blank transparencies
- Dry erase markers (sharp point)
- Navigational Charts for each harbor or section of shoreline
- Binoculars
- Ruler
- Graph Paper

Station Logistics and Safety - Two students can work together on this task and then should rotate so that one student does one section of shoreline and the second student does another. The first should call out the shoreline use, the second student should record the information. Binoculars should always have a neck strap which is worn at all times to prevent dropping or banging the binoculars.

Getting Started - Ask students what activities they do along a shoreline. Some will say swimming, boating, or fishing. Others may say they go to museums, aquaria or other educational institutions. Many may not be able to identify what a shoreline is. In any case, however, each student should be able to list at least one use of the shore. Use this list as a starting point.

Procedures - Lay out a navigational chart of the area from which the ship will sail (harbor, for example). Show the students where they are and which way they will be sailing. Take a blank transparency and a sharp pointed dry erase marker and trace the shoreline. More than one sheet of transparency may be needed to cover the entire area. Locate a starting point (landmark, building, geologic feature) on the navigational chart and on the traced transparency. This point is the start for the survey. With the naked eye or binoculars, examine the shoreline and mark on the transparency for each of the uses. The students should create a code (such as a letter or number for each use - repeating the letter or number along the shore if the area covered by that use is larger than a single number or letter) Among the uses of the shoreline are the following categories:

- open, natural (woods, marshes, beaches, rocky shores)
- open, disturbed space (city lots, abandoned land)
- single family housing including beach homes
- multiple family housing (apartment buildings, large and small) office buildings marinas and boat yards
- docks, piers
- industrial buildings
- museums
- amusement parts, aquaria or other recreation
- waste water (pollution) treatment plants
- farms
- roads
- other (specify)

Findings and Observations -Students should end with a map of the shore which shows the type, location and amount of development along the shore they are surveying. They should then measure with the ruler how much of the shoreline is in each use and to convert that information into percentage use. Alternatively they can transfer the information to graph paper, placed over the transparency and traced, which will allow students to estimate the amount of shoreline in each use based on the number of squares of area in each category.

What do the Findings Mean? -Each use of the shoreline has its costs and benefits. Few are totally impact free on the waters along the shore and in near shore areas. Homes, single family and multiple dwellings, have septic leaving them. For homes right on the shore in relatively undeveloped areas, on site septic systems may be the means of waste disposal, possibly adding both bacteria and nitrogen to the coastal environment (see activity on dissolved oxygen). Industrial waste, largely regulated today, still finds its way into the water either directly, with a discharge permit from the state, or indirectly through the waste water treatment plants. Farms have runoff of manure, fertilizers and pesticides, all of which have an impact on the coast. Open space, including natural areas, can have runoff which, although “organic” can color or otherwise impact nearshore waters.

One figure may help students understand the scale of inputs. All the rivers that flow into Boston Harbor, combined contribute 500,000,000 gallons of water each day. The waste water treatment plant on Deer Island in Boston Harbor releases 450,000,000 gallons of water into the harbor every day!

Discussion Questions -

1. What use of the shoreline dominates this area?
2. What might the impact of this shoreline use be on the nearby environment?
3. Which of the shoreline uses do the students have a role in or use?
4. Why have these shoreline uses developed overtime?

Connections - People want to live and work near the shore. At present 50% of the world's population lives in the coastal zone a number of people which is estimated to double in the next 25 -30 years. People used the coast, at one time, as

not only a port from which to leave and enter Massachusetts, but also a dump for our household and industrial wastes, a source of cooling water, a source of fish and **shellfish** and many other activities, many of which can be mutually exclusive.

As more and more upland areas in **watersheds** were developed and as homes, industries, and farms became concentrated in these regions more and more water ran off the land to the sea. Scientists believe that the growth of **population** in our coastal areas, and along rivers, has led to the contamination of our harbors, loss of wildlife and natural areas (there is 50% less salt marsh acreage today than 50 years ago) and a change in the coastal **ecosystem**. While the problem might have been caused by large pipes carrying wastes to the sea in the past (**point source pollution**), we now know that more and more the cause of coastal **pollution** is small amounts of waste (**non-point source pollution**) entering the system. These wastes include small amounts of petroleum products from each gasoline powered boat; fertilizers and pesticides, not just from farms but from individual homes; **run-off** from roads carrying salts and animal wastes; household hazardous wastes; septic system leaching; and similar small scale but cumulatively tremendous volumes of wastes.

Links to Other Activities -Salty Seas (**salinity**) allows students to connect the **salinity** study to human sources of fresh water such as waste water treatment plants and rivers. The Shoreline Survey can be compared to the findings from the **dissolved oxygen** (Breathing Waters), minnows (Tiny Fish), crabs (Nasty, Nasty Claws) and activities. In combination these activities should provide a basis for discussions of how what we do on the land affects what happens in the water and what lives there.

Estimated Time on Task - 10 - 15 minutes

Links to Curriculum Frameworks -

K - 4 - Planning and conduct a simple investigation knowing what is to be compared or looked for; extend observations using simple tools; recognize and communicate simple patterns in data; identify, describe, and create a wide variety of patterns; use patterns and relationships to analyze mathematical situations; interpret findings by relating one factor to another.

5 - 8 - note and describe relevant details patterns and relationships; identify, describe, and create a wide variety of

patterns; use patterns and relationships to analyze mathematical situations; analyze functional relationships to explain how a change in one quantity results in a change of another; use tables and graphs to interpret expressions, equations and inequalities; describe ranges in data even when patterns are not exact; analyze alternative explanations and procedures.

9 - 10 - formulate testable questions and generate explanations using the results of predictions; test hypotheses by using appropriate statistics; transform data to aid in data interpretation and prediction; make decisions about the range and number of independent variables and how to control other variables in designing experiments.

Application of Frameworks - Students will be asked to predict the general levels (not specific numbers) of pollution at various locations based on their location and observations of water quality and land use. The students can pose questions to be answered such as "what are the impacts which each land use has both on the nearby shoreline and on the waters along the coast" or "why are the uses which we observed concentrated along the shore" or similar questions which they might answer from their observations.



Contacts List

Boston Harbor and Massachusetts Bays (partial list of Local references and resources)

Massachusetts Bays Project

Massachusetts Coastal Zone Management
100 Cambridge Street
Boston, MA 02202
Phone (617) 727-9530 ext 424
Fax (508) 727-7235

Contact -Ms. Elizabeth (Betsy) McEvoy for information on the project

Save the Harbor/Save the Bay

25 West Street
Fourth Floor
Boston, MA 02111
Phone (617) 451-2860
Fax (617) 451-0496
email: shsb@tiac.net

Contact Jodi Sugarman for information

Massachusetts Water Resources Authority

Harbor Studies Unit
Sewerage Division
100 First Ave
Charlestown Navy Yard
Boston, MA 02129
Phone (617) 242-6000
Fax (617) 241-6550
email: enquad@worldstd.com

Contact Tim Watkins (Public Affairs) for general information; Dr. Michael Connor or Dr. Andrea Rex (241-6510) for Boston Harbor Monitoring information or Kenneth Keay (241-6504) for Massachusetts Bays Monitoring

Selected References and Resources

Teachers will be able to find a wealth of information available to them regarding each of the regions of Massachusetts and the overall condition of Massachusetts waters. Curriculum materials, including classroom activities, field trip ideas and media are accessible throughout the state. Below is a brief selection of materials which can serve as references or sources of information for the teacher in advance or after a Expedition to the Water Planet aboard the Schooner ERNESTINA.

Videos:

Sea Behind the Dunes (coastal and salt marsh ecology, Pleasant Bay)

Ghost of the Great Auk (regional overview from kayak perspective with discussions of fisheries issues of entire region)

Turning the Tide : Keeping Pollution at Bay (produced by Buzzards Bay National Estuary Project but appropriate for entire region of coastal Massachusetts - water pollution focus - available also for Massachusetts Bays region)

Voyage of the Mimi (videos and curriculum less focused on the region but directed at the concepts of student active learning on board a sailing vessel)

Books and Publications:

All About the Boston Harbor Islands, by Emily and David Kale

The Atlantic Shore: Human and Natural History from Long Island to Labrador, by John Hay and Peter Farb

Changes in the Land, Indians, Colonists and the Ecology of New England, by William Cronon

Dirty Water, Clean Water: A Chronology of Events Surrounding the Degradation and Cleanup of Boston Harbor, by Eric Jay Dolin

A Field Guide to the Eastern Birds , by Roger Tory Peterson

A Field Guide to the Atlantic Shore, by Kenneth L. Gosner

A Field Guide to Atlantic Coast Fishes, by C. Richard Robins and G. Carleton Ray

A Geologists View of Cape Cod, by Arthur N. Strahler

A Guide to New England's Landscape, by Neil Jorgensen

A Sierra Club Naturalist's Guide - The North Atlantic Coast, Cape Cod to Newfoundland , and *A Sierra Club Naturalist's Guide - The Mid-Atlantic Coast* by Michael and Deborah Berrill (out of print but the best all around resource books on the ecology of these regions)

The Sierra Club Handbook of Whales and Dolphins , by Stephen Leatherwood and Randall R. Reeves

Other Sources, Publications and Resources:

Three of the most valuable sources for information on the region are the Massachusetts Water Resources Authority (Boston Harbor and Massachusetts Bay), and the two National Estuary Programs; the Buzzards Bay Project and the Massachusetts/Cape Cod Bay Project. Available from these agencies are a rich selection of materials which provide scientific background on water quality, living resources, human impacts and research underway to characterize and protect the coastal and marine environment. Also valuable for information are the Stellwagen Bank National Marine Sanctuary (Plymouth), the Massachusetts Office of Coastal Zone Management, and each of the regional planning agencies, local conservation and shellfish/natural resource departments throughout the Commonwealth.

Within each region non-profit and other groups and agencies are working to monitor the water quality and human impacts of Massachusetts waters. These are listed in each of the sections of the curriculum and should be contacted for the most up to date monitoring data and reports. Nearly all have resource libraries of other means for disseminating information on their work. For teachers and others interested in the region, the Teacher Resource Center and Library of the New England Aquarium has compiled an extensive collection of materials including curricula, kits, a reference book collection and teaching aids.

Three government publications of special value are:

Buzzards Bay Comprehensive Conservation and Management Plan, and supporting documents and reports

Massachusetts /Cape Cod Bay Comprehensive Conservation and Management Plan and supporting documents and reports

The State of Boston Harbor Annual Report from the Massachusetts Water Resources Authority

Figure II-1. The Massachusetts Bays Region



Salem Sound Region



Maps and Charts

1992 DEP Water Quality Ratings for Salem Sound's Major River Basins & Harbors

<u>River Segment</u>	<u>Use *</u> <u>Class</u>	<u>Status**</u>	<u>Pollutants - Sources</u>
Bass River - headwaters to inlet of Shoe Pond, Beverly	B	PS	organic enrichment / DO, pathogens - source unknown, urban runoff / storm sewers
Bass River - inlet Shoe Pond to Danvers River	SB	PS	pathogens - source unknown, urban runoff / storm sewers
Danvers River	SB	NS	pathogens-source unknown, urban runoff / storm sewers, combined sewer overflow
Porter River	SB	NS	pathogens - source unknown, urban runoff / storm sewers
Crane River	SB	NS	pathogens - source unknown, urban runoff / storm sewers
continued			

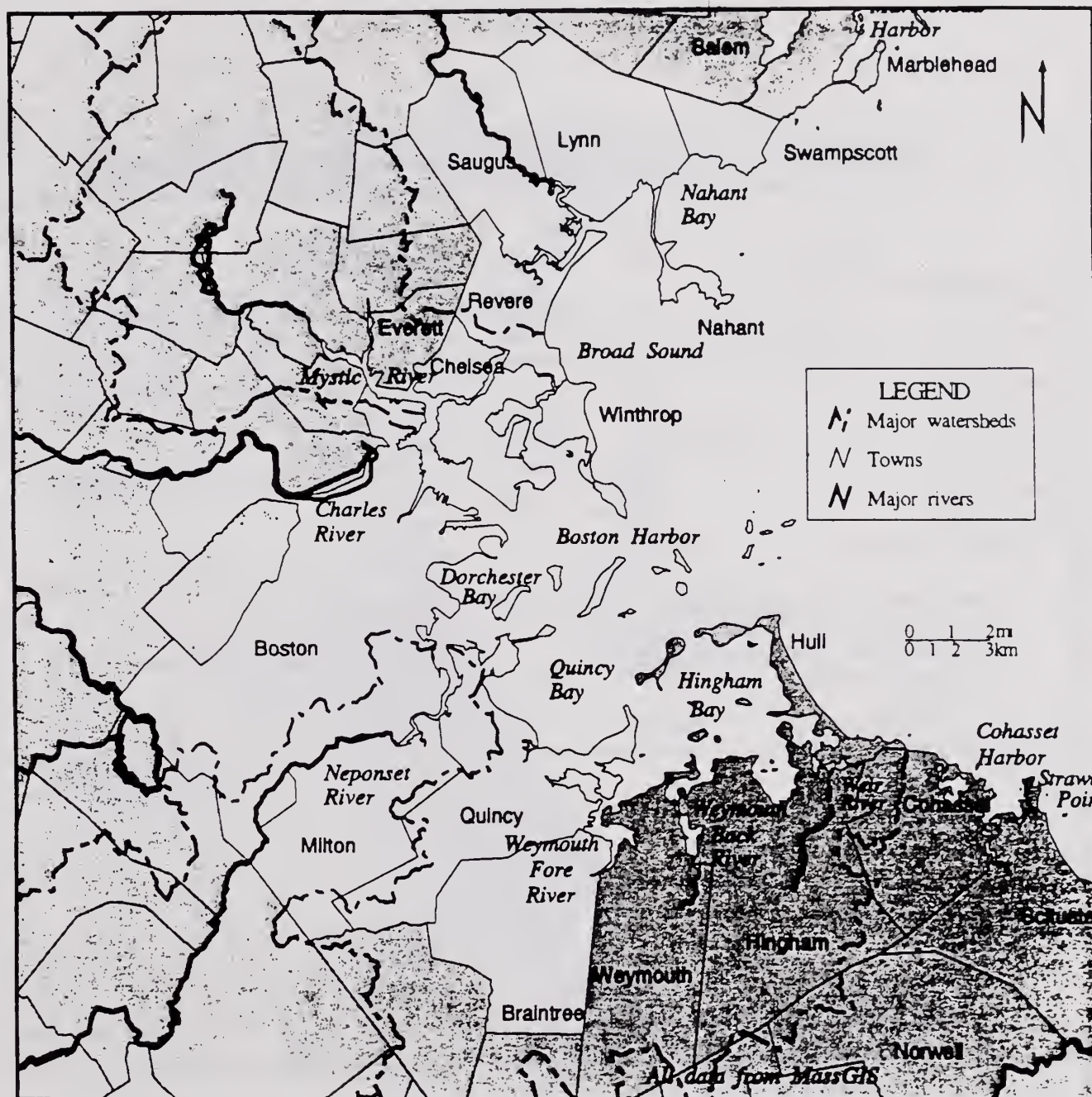
Maps and Charts

1992 DEP Water Quality Ratings for Salem Sound's Major River Basins & Harbors

<u>River Segment</u>	<u>Use *</u> <u>Class</u>	<u>Status**</u>	<u>Pollutants - Sources</u>
Crane Brook	B	NS	unionized ammonia, pathogens - source unknown, urban runoff / storm sewers
Waters River	SB	NS	pathogens - source unknown, urban runoff / storm sewers
North River	SB	NS	nutrients, organic enrichment/DO, pathogens - industrial point sources, source unknown, urban runoff / storm sewers
Goldthwait Brook	B	NS	pathogens, nutrients, organic enrichment/DO, unionized ammonia - urban runoff / storm sewers, source unknown, industrial point sources
Forest River	SB	NS	pathogens, organic enrichment/DO, nutrients, unionized ammonia - urban runoff / storm sewers, source unknown
Manchester Harbor	SB	NS	pathogens - septic tanks, recreational activities, source unknown, municipal point sources
Beverly Harbor	SB	NS	pathogens - CSOs, recreational activities, source unknown, urban runoff / storm sewers
Salem Harbor	SB	NS	pathogens - urban runoff / storm sewers, recreational activities, industrial point sources
Marblehead Harbor	SA	NS	pathogens - CSOs, urban runoff/storm sewers, source unknown, recreational activities
* <u>"Use Classes"</u> are state goals for the river: S prefix denotes coastal or marine segment A = public water supply, fishable, swimmable B = fishable, swimmable C = fishable			** <u>Status Codes:</u> S = supports all indicated uses S/T = supports all uses, but threatened PS = supports some uses NS = supports no uses

Source: DEP 305(b) Report

Metro Boston Region



Maps and Charts

1992 DEP Water Quality Ratings for Metro Boston Rivers and Harbors

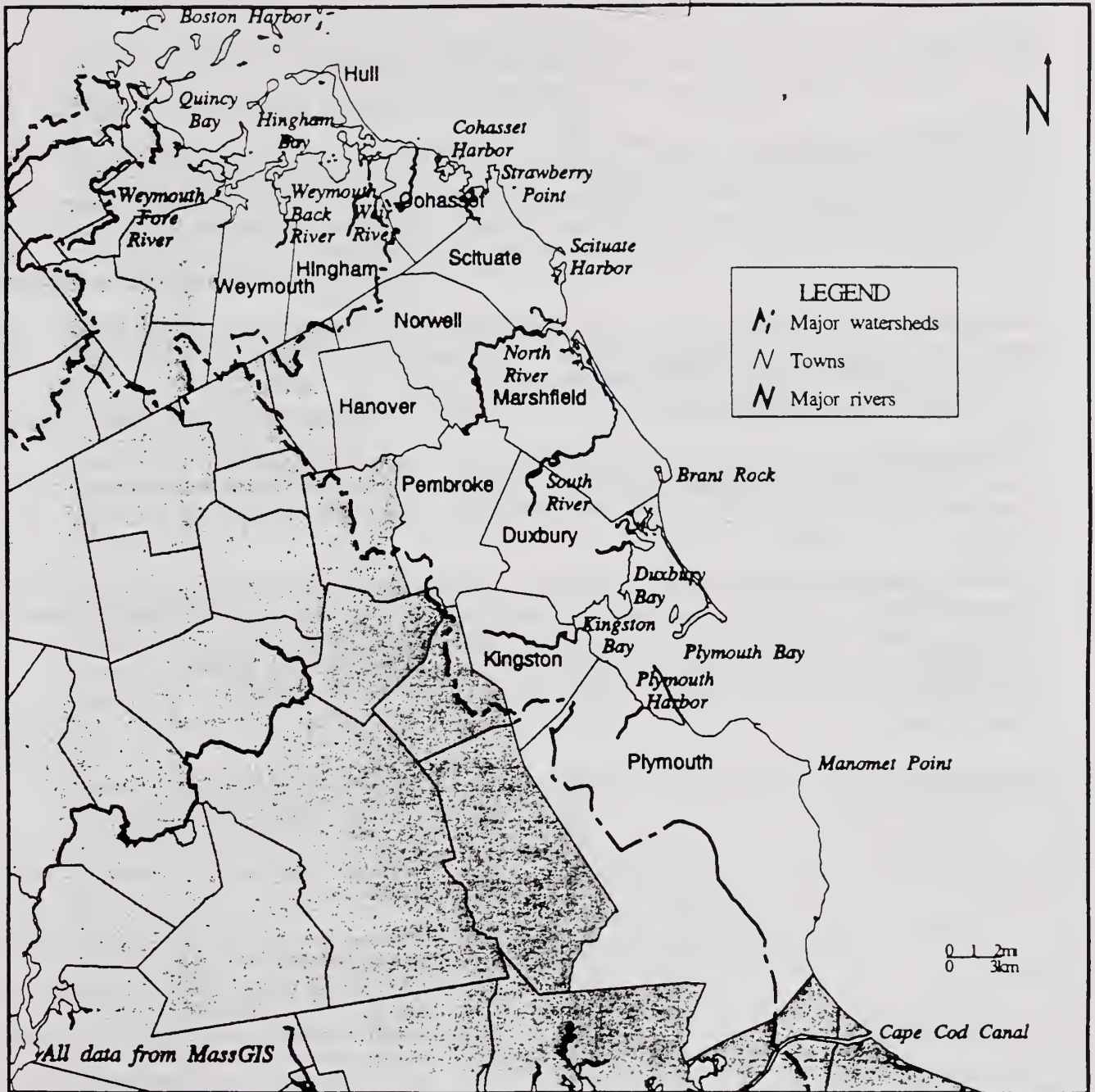
<u>River/Harbor</u>	Use * <u>Class</u>	<u>Status**</u>	<u>Pollution Sources</u>
Nahant	SA	NS	Runoff, Wastewater Treatment Plant (WWTP) outfall
Lynn Harbor	SB	NS	Runoff, WWTP, CSO
Pines River	SB	NS	Septic systems
Saugus River	B/SB	NS	Septic systems, runoff, CSOs, industrial outfall
Chelsea River	SB	NS	CSO, urban runoff
Mystic River	SB	NS	CSO, urban runoff
Charles River	B	NS	Urban runoff, CSOs, inplace contamination
Neponset River	SB	NS	CSO, runoff
Furnace Brook	B	NS	Runoff
Weymouth Fore River	SB	NS	Runoff

* "Use Classes" are state goals for the river:
 S prefix denotes coastal or marine segment
 A = public water supply, fishable, swimmable
 B = fishable, swimmable
 C = fishable

** Status Codes:
 S = supports all indicated uses
 S/T = supports all uses, but threatened
 PS = supports some uses
 NS = supports no uses

Source: DEP 305(b) Report

South Shore Region



Maps and Charts

1992 DEP Water Quality Ratings for South Shore Rivers and Harbors

<u>River Segment</u>	<u>Use Class*</u>	<u>Status**</u>	<u>Pollutants - Sources</u>
The Gulf	SB	NS	pathogens septic tanks, non-urban runoff
Bound Brook	B	S	
North River (Curtis Crossing Dam to 3A)	SA	NS	organic enrichment/DO, pathogens - septic tanks, non-urban runoff, septage disposal, natural
North River (3A to mouth)	SA	PS	pathogens - septic tanks, non-urban runoff
Herring River	SA	PS	pathogens - septic tanks, recreational activities, non-urban runoff, marinas
Indian Head River	B	PS	nutrients, organic enrichment/DO - municipal point sources, natural
French Stream	B	PS	organic enrichment/DO, nutrients, pathogens - natural, municipal point sources, non-urban runoff
South River (South Res., Duxbury to Main Street, Marshfield)	B	S	
South River (Main Street, Marshfield to North River)	SA	NS	unionized ammonia, pathogens, organic enrichment/DO - non-urban runoff, septic tanks, natural
Green Harbor River	B	PS	pathogens - septic tanks
Jones River (Silver Lake to Wapping Pond, Kingston)	B	S	
Jones River (Wapping Pond to Elm Street, Kingston)	B	S	
Jones River (Elm Street to mouth, Kingston)	SA	NS	pathogens - non-urban runoff
Cohasset Harbor	SA	NS	pathogens - septic tanks, municipal point sources, non-urban runoff
Scituate Harbor	SA	PS	pathogens - source unknown
Green Harbor	SA	NS	pathogens - septic tanks
Duxbury Bay	SA	S	
Plymouth Harbor	SA	NS	pathogens - municipal point sources, urban runoff/storm sewers
Plymouth Bay	SA	NS	pathogens - source unknown
Furnace Brook	S	NS	organic enrichment - urban runoff
Weymouth Fore River	SB	NS	pathogens - urban runoff, storm sewers
Town Brook	S	S	
Monatiquot River	B	NS	pathogens, organic enrichment - septic tanks, urban runoff
Farm River	S	S	
Cochato River	B	NS	pathogens, organic enrichment - septic tanks, urban runoff
Trout Brook	S/T	S	oil and grease, priority organics - waste storage, leaks, spills
Weymouth Back River	B	NS	organic enrichment, pathogens, DO - urban runoff, septic systems
Mill River	A	NS	noxious aquatic plants, pathogens, nutrients - septic tanks, urban runoff
Old Swamp River	A	NS	pathogens, organic enrichment/DO - urban runoff, septic systems
Weir River	SA	NS	nutrients, pathogens
Crooked Meadow River	B	NS	organic enrichment, nutrients - urban runoff, septic tanks
Town River Bay	SB	PS	organic enrichment/DO, pathogens - urban runoff

* "Use Classes" are state goals for the river:
 S prefix = coastal or marine segment
 A = public water supply, fishable, swimmable
 B = fishable, swimmable
 C = fishable

** Status Codes:
 S = supports all indicated uses
 S/T = supports all uses, but threatened
 PS = supports some uses
 NS = supports no uses

Monitoring Plans

DRAFT MWRA Harbor Monitoring Plan, 1996

1. CSO Receiving Water Monitoring

Purpose: To gather data which will measure the effect of CSOs on the receiving waters, in order to satisfy MWRA's NPDES permit requirements, to relate bacteria counts in the water to rainfall, and to measure changes in water quality over time as CSO remediation plans are effected.

Rationale: The most damaging effect of untreated CSOs is acute pollution of the receiving waters with the disease-causing microorganisms found in sewage. This public health threat can put those who swim or eat shellfish from contaminated water at risk for infectious diseases and cause the closure of shellfish beds and beaches. Therefore, the CSO monitoring program focuses on measuring bacterial pollution in the water column, with intensive monitoring of *Enterococcus* and fecal coliform bacterial indicators.

Sampling stations are located in all CSO receiving waters, with locations both near to and distant from CSO outfalls. Each receiving water area is monitored daily for four successive weeks, during both wet and dry weather. This type of intensive sampling schedule has enabled us to track the increase and decrease over time of bacterial indicators in the water resulting from rainstorms.

The data are analyzed to determine how well water quality standards are met, and how pollution levels relate to rainfall. As several years of data accumulate, statistical analyses can help to determine if the relationship between precipitation and bacteria levels in the receiving waters changes over time.

The receiving water monitoring for bacteria is complemented by sediment monitoring near selected CSOs for priority pollutants and metals. The rationale for sampling sediments for toxic contamination is that while acute criteria in the water column are rarely violated, toxic chemicals, because they attach to particles, may sink to the bottom and accumulate. The second sediment toxic chemical survey was completed in the fall of 1994, and a third survey is planned for 1998.

CSO Receiving Water Monitoring Parameters	
Date, Time, Tide Stage, Water Depth	
<i>In situ</i>	Laboratory
Temperature	Fecal coliform
Dissolved oxygen percent saturation	<i>Enterococcus</i>
Dissolved oxygen (mg/l.)	
Salinity	
Conductivity	
Turbidity	
pH	
Secchi depth	

Monitoring Plans

CSO Effects Monitoring 1996 Mystic River and Chelsea River			
Sampling Schedule June 10-July 6 Monday through Saturday			
Station	Location	Coordinates	Sample Depths
27	Chelsea River		Surface and Bottom
15	Confluence of Mystic and Chelsea Rivers		Surface and Bottom
69	Mouth of Mystic River at Schrafft's boat dock		Surface and Bottom
52	Mystic River, near Somerville Marginal outfall		Surface and Bottom
59	Confluence of Mystic and Malden Rivers		Surface
56	Mystic River, near Rt. 93 Bridge		Surface
57	Confluence of Mystic River and Alewife Brook		Surface
83	Mystic River upstream of Alewife confluence		Surface
70	Alewife Brook at subway station		Surface

CSO Effects Monitoring 1996 Charles River, Inner Harbor and Constitution Beach			
Sampling Schedule July 8-August 3 Monday through Saturday			
Station	Location	Coordinates	Depths Sampled
019	Mouth of Fort Point Channel		Surface and Bottom
018	Fort Point Channel, Summer St. Dr.		Surface
075	Fort Point Channel, Broadway Br.		Surface and Bottom
015	Confluence of Mystic and Chelsea Rivers		Surface and Bottom
014	Mouth of Charles River		Surface and Bottom
012	Watertown Dam off footbridge		Surface
011	Charles R. betw RR bridge and Sci Mus		Surface and Bottom
145	Charles R. MWR 023 Stony Brook		Surface
008	Charles R. Basin dwnstrm of Harvard Br		Surface and Bottom
006	Charles R. B.U. Bridge, Cottage Farm		Surface
005	Charles R. upstream of Cottage Farm		Surface
144	Charles R. at BOS 032		Surface
098	Constitution Beach CSO		Surface
091	Constitution Beach storm drain		Surface

Monitoring Plans

CSO Effects Monitoring 1996 Dorchester Bay, Neponset River and Moon Is.			
Sampling Schedule August 5- August 30, 1966 Monday through Saturday			
Station	Location	Coordinates	Depths Sampled
024	Mouth of Inner Harbor red buoy #10		S+B
044	Dorchester Bay near Spectacle, green buoy #5		S+B
028	Pleasure Bay		S
038	Mid-Old Harbor		S+B
033	Carson Beach, off L-Street Bathhouse		S
036	Carson Beach Bathhouse		S
084	Mouth of Neponset, off Columbia Pt. red buoy #12		S+B
039	Savin Hill Cove, off U. Mass dock		S
040	Malibu Bay		S
089	Commercial Pt, Victory Rd Foothridg		S
041	Neponset R. Old Colony Yacht Club		S
100	Tenean Beach		S
###	Tenean Beach MDC drain		S
###	Tenean Beach MDC drain		S
042	Neponset River near BOS-093		S+B
054	Neponset River, Granite Ave		S
055	Neponset River, dam at chocolate factory		S
048	Quincy Bay off Moon Island		S+B

Monitoring Plans

1996 Treatment Plant Effects Monitoring	
Purpose: measure bacteria at WWTP outfalls and nearfield stations. Correlate levels of bacteria in receiving water with levels in effluent to determine effects of treated effluent on receiving waters.	
Samples collected twice per month, year-round as weather permits.	
Date, Time, Tide Stage, Water Depth	
<i>In situ</i>	Laboratory
Temperature	Fecal coliform
Dissolved oxygen percent saturation	<i>Enterococcus</i>
Dissolved oxygen (mg/L)	
Salinity	
Conductivity	
Turbidity	
pH	
Secchi depth	

Nut Island Effects		
Station	Location	Depths Sampled
079	Nut Is. Outfall #103	Surface
081	Nut Is. Outfall #102	Surface
082	Nut Is. Outfall #101	Surface
080	Quincy Yacht Club, red buoy #2	Surface
047	Quincy Bay off Wollaston Beach	Surface
086	Back River, Downstream of pumping stations	Surface
116	Fore River, red nun #28	Surface
117	Iltingham/Hull Bay	Surface
Deer Island Effects		
Station	Location	Depths Sampled
160	Deer Is. Outfall #001 (at diffuser)	Surface
159	Deer Is. Outfall #002 (at diffuser)	Surface
118	Lovell Island	Surface
065	President Roads	Surface and Bottom
135	Boston North Channel	Surface and Bottom
136	Boston South Channel	Surface and Bottom
050	Calf Island	Surface
105	Nixes Mate	Surface
129	Governor's Island	Surface

Monitoring Plans

III. Long Term Boston Harbor Water Quality Monitoring (BHWQM)

Purpose: To gather data which will document present conditions Harbor-wide and provide a baseline for comparing water quality changes as improved primary treatment, secondary treatment, and the new outfall and diffuser are implemented.

Rationale: Because MWRA's treatment plants either are or have been major sources of bacteria, suspended solids, and nutrients to Boston Harbor, parameters selected focus on the effects of these pollutants. Sites are "representative" of different geographic areas of the harbor. Sampling is random with respect to weather. Measurements complement other long-term studies in the harbor, including EPA priority pollutants/toxic chemicals by toxicity testing effluent, "mussel watch" studies; sediment sampling of benthic fauna and penetration of dissolved oxygen; health of lobster and flounder populations; phytoplankton species and macrolagae; and modeling of harbor circulation.

Long Term Boston Harbor Water Quality Monitoring (BHWQM)	
Date, time, stage of tide, depth of water	
Sampling schedule: Bimonthly January-May; October-December; Weekly June-September	
Samples collected at surface and bottom at all sites	
<i>In situ</i>	<i>In Laboratory</i>
Temperature	Fecal coliform
Dissolved Oxygen percent saturation	<i>Enterococcus</i>
Dissolved Oxygen (mg/L)	Total Suspended Solids
Salinity	Total Nitrogen
Conductivity	Ammonia
Turbidity	Total Phosphorous
pH	Phosphate
Photosynthetically Active Radiation	Chlorophyll a
Secchi depth	Phaeophytin

Station	Location	Coordinates
137	Mystic River, mouth	42° 23.20N, 71° 03.80W
138	Inner Harbor	42° 21.59N, 71° 02.82W
024	Inner Harbor	42° 20.59N, 71° 00.48W
140	Neponset River, mouth	42° 18.35N, 71° 02.43W
139	Hangman's Island	42° 17.20N, 70° 58.10W
124	Hingham Bay	42° 16.36N, 70° 53.86W
141	Peddock's Island	42° 18.30N, 70° 55.85W
142	President Roads	42° 20.35N, 70° 55.89W
077	Quincy Bay	42° 16.51N, 70° 59.31W
106	Long Island	42° 20.00N, 70° 57.60W

Monitoring Plans

Other monitoring studies:

Anthropogenic Viruses	
Sampling schedule-- May 1996- One survey during wet weather conditions, and one survey during dry weather conditions.	
Purpose-- Second survey to measure the level of contamination of Boston Harbor by anthropogenic viruses, near the WWTPs, Carson Beach, Wollaston Beach, Fort Point Channel (untreated CSO), the Charles River (Stony Brook), Somerville Marginal outfall (treated CSO).	
Date, Time, Tide Stage, Water Depth	
<i>In situ</i>	Laboratory
Temperature	Fecal coliform
Dissolved oxygen percent saturation	<i>Enterococcus</i>
Dissolved oxygen (mg/L)	Cultivable viruses (Enteroviruses)
Salinity	Non-cultivable viruses (by PCR) Norwalk, Rotavirus, Hepatitis A
Conductivity	Coliphages
Turbidity	
pH	

"IM3" Study of Charles River with Charles River Watershed Assn. Measurements of bacteria, nutrients, metals many sites upstream of CSO area. Surveys approximately monthly. Three stormwater effects surveys in early spring.

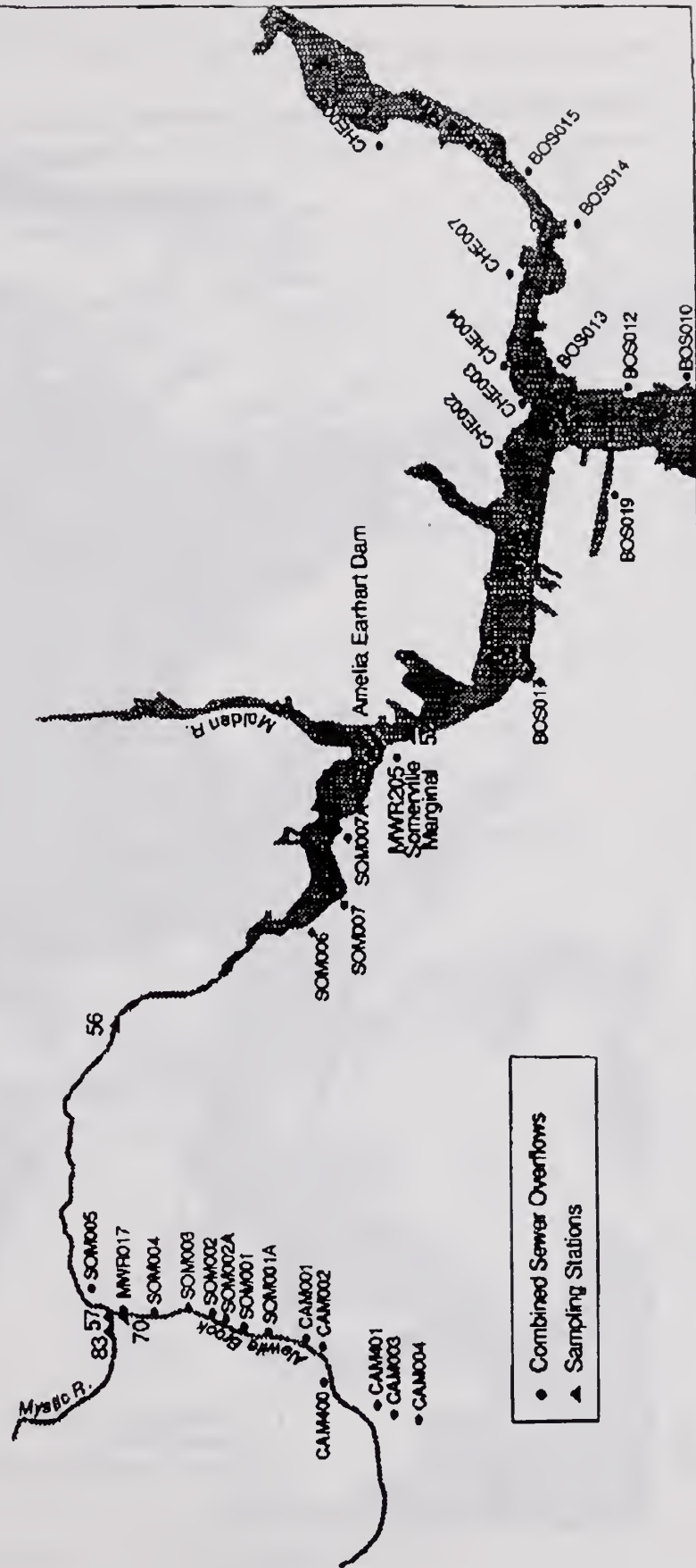
Fore River Embayment Study with Mass Bays Program/Fore River Watershed Assn. Measurements of fecal coliform, *Enterococcus*, and *E. coli* at sites in Fore River and its tributaries which are potentially affected by "nonpoint" sources such as stormwater, sewer overflows, boats. Several surveys during wet and dry weather.

Mooring offshore of New England Aquarium--Moored sensors measure DO, T, Sal at surface and bottom. Record data hourly.

MDC intensive beach monitoring cooperative study MDC will collect samples daily at three beaches: Wollaston, Carson and Constitution. MWRA Central Lab will analyze samples. Purpose: to improve understanding of relationship between rainfall and beach water quality.

Monitoring Plans

MWRA CSO Monitoring Stations, Mystic River, Chelsea River, Alewife Brook, 1996



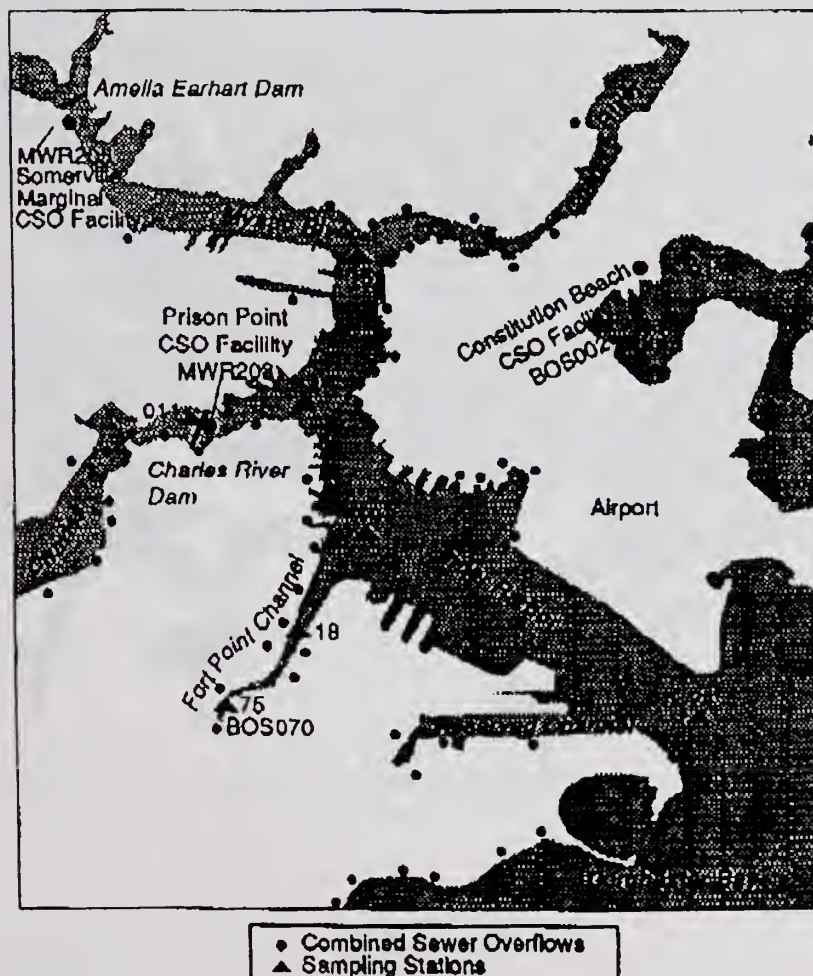
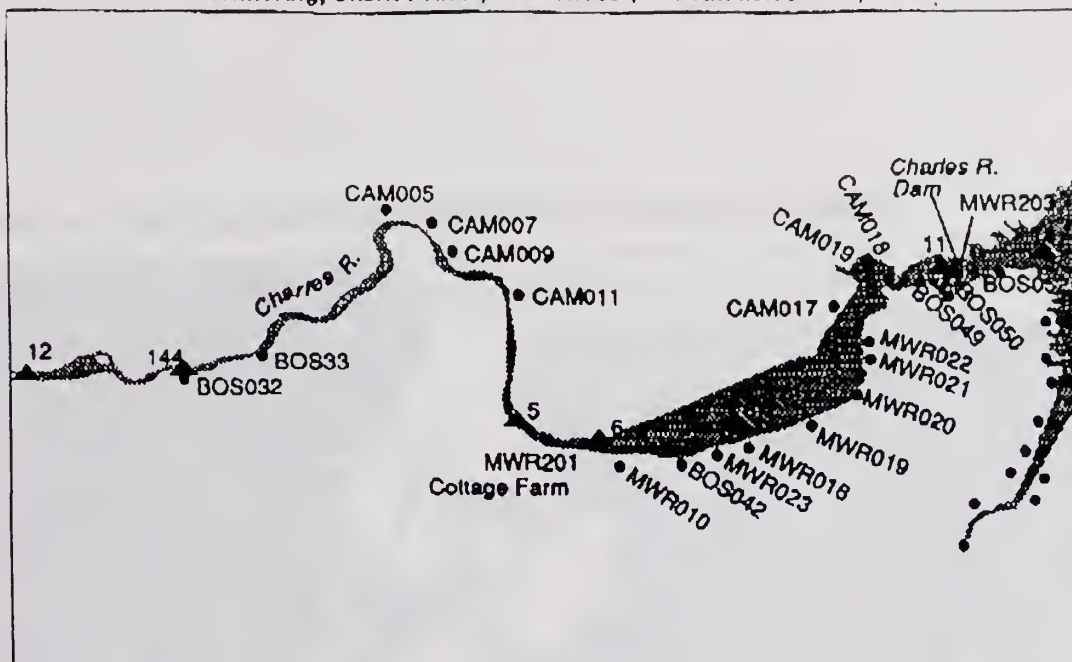
Monitoring Plans

MWRA CSO Monitoring Stations Dorchester Bay and Neponset River, 1996



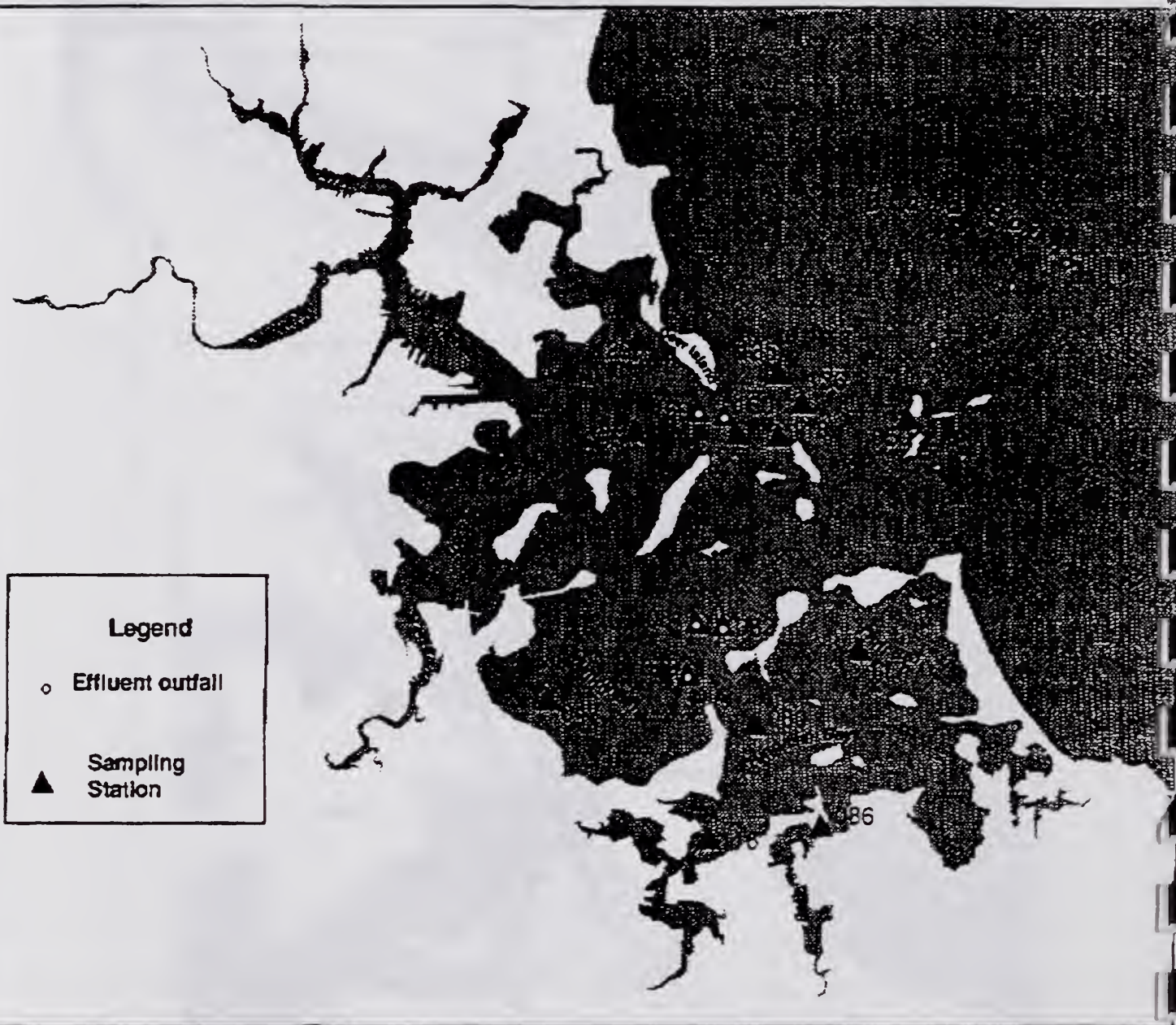
Monitoring Plans

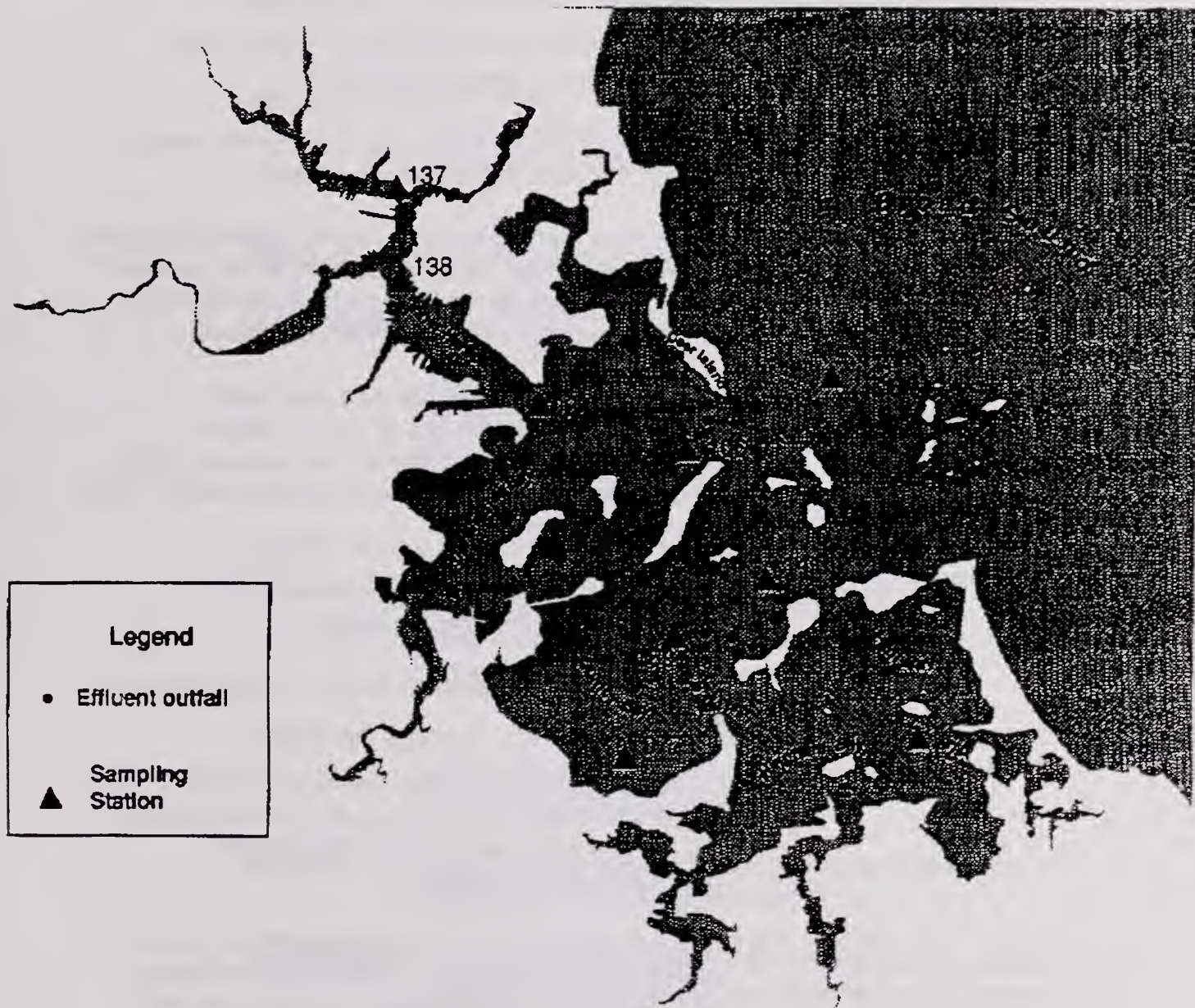
MWRA CSO Monitoring, Charles River, Inner Harbor, Constitution Beach, 1996



Monitoring Plans

MWRA Treatment Plant Effects Monitoring Stations 1996



MWRA Boston Harbor Water Quality Monitoring Stations 1996

Glossary

abiotic - nonliving components of an **ecosystem**, including chemical and physical factors such as temperature, rainfall and **nutrients**.

algal bloom - rapid growth of algae in surface waters due to increase in inorganic **nutrients**, usually nitrogen or phosphorus.

aquaculture - cultivation of fish and other aquatic organisms in fresh and salt water bodies.

aquifer - underground layer of porous material, usually rock containing water (**groundwater**).

beaches - the shore of a body of water, especially when sandy or pebbly; the sand or pebbles on a shore.

benthos - those animals and plants living on the bottom of the sea or lakes, from high water mark down to the deepest levels; the **benthos** is divided into littoral (down to 200 meters deep) and deep water organisms.

bioaccumulation - the process by which a contaminant accumulates in the tissues of man individual organism; certain chemicals in food eaten by a fish tend to accumulate in its liver and other tissues. (also bioconcentration).

biomagnification - buildup of chemicals or substances in successively higher **trophic levels**.

biomass - the dried weight of all organic matter in a section of an **ecosystem**.

biosphere - the part of the earth and its atmosphere in which living organisms exist or that is capable of supporting life; the living organisms and their environment composing the **biosphere**.

biotic - the biological components of an **ecosystem**, consisting of plants, animals, fungi, microorganisms and other living things in an **ecosystem** and their products.

climate - the average weather conditions, including temperature, sunlight, precipitation and humidity.

coastal zone - that area adjacent to a body of water which is impacted by the physical, chemical or biological attributes of that water body; the upland area from the shoreline to an inland point where the effects of the water are no longer felt.

coliform bacteria - common **bacteria** found in the intestinal tracts of warm blooded animals, including birds and mammals; a measure or indicator of potential **pathogens** in a body of water derived from fecal contamination.

community - the interacting **population** of animals, plants and all other organisms living in a given location.

current - passing from one to another; circulating; the part of a body of liquid or gas that has a continuous onward movement; a general tendency, movement, or course.

detritus - organic waste from animals or plants.

dinoflagellates - a group of microscopic, photosynthetic single celled algae known to form endo**toxins**; red **tide** organisms which produce endo**toxins** which are biomagnified and bioaccumulated in coastal and other marine organisms, (clams) and can lead to paralytic **shellfish** poisoning.

Dioxin - any of several carcinogenic or teratogenic heterocyclic hydrocarbons that occur as impurities in petroleum-derived herbicides and as a bi-product of the incineration of petroleum-derived materials (i.e. plastics).

dissolved oxygen - amount of molecular oxygen in a water solution; measured in parts per million (ppm) and dependent on water temperature.

ecology - the study of living organisms and their relationships to one another and the **abiotic** world.

ecosystem - a **community** of organisms occupying a given region within an ecological zone; the physical and chemical environment and interrelationships of that **community**.

ecotone - transition zone between two **ecosystems**.

endangered species - a group of self-reproducing organisms which are in immediate danger of biological extinction.

estuary - coastal regions where salt and fresh water meet; part of the wide lower course of a river where its **current** is met by the **tides**; an arm of the sea that extends inland to meet the mouth of a river.

eutrophication - accumulation of **nutrients** in a body of water which can occur naturally or as a result of human intervention (contamination). (nutrient enrichment).

fecal coliform - **bacteria**, found in warm blooded animals, which are used as indicators of water contamination by **sewage** and other wastes

food web - complex intermeshing of individual nutrient and energy pathways in an **ecosystem**. (food chain - pathway from producer to consumer in and **ecosystem**).

groundwater - water below the earth's surface in a saturated zone.

gyre- a **current**, often circular in nature, which branches off of larger ocean **currents**.

habitat - the specific region where an organism lives.

heavy metals - mostly the reactive ions of metals which are used in industry, boating (such as historically in some paints) and in some household products which can act as toxics (poisons). Lead, chromium, selenium, copper and manganese are examples of **heavy metals**.

immigration - movement of people into a country to set up residence there.

limiting factor - a chemical or physical factor that determines whether a **species** can survive in a specific **ecosystem**.

monitoring - keep track of systematically with a view to collecting information; to test or sample on a regular or ongoing basis; to keep close watch over; supervise; on-going sampling which scientists and citizens do to determine if there are changes in the biology, chemistry or physical aspects of an **ecosystem**.

non-point source - diffuse, often intermittent, sometimes ill-defined inputs including surface **run-off**, rainfall, atmospheric deposition, underground transport and leaching of materials through **groundwater**.

pathogen - parasite which causes disease.

pathogenic - disease causing.

PCB's - polychlorinated biphenols - organic compound - known carcinogen and mutagen; can cause miscarriages; used as an insulator in electrical equipment until banned (1972).

pH - measure of acidity and alkalinity (basic) on a scale from 0 - 14 with 7 as neutral, less than 7 acidic, more than 7 alkaline (basic).

plankton - the collection of small or microscopic organisms, including algae and protozoans, that float or drift in great numbers in fresh or salt water, especially at or near the surface, and serve as food for fish and other larger organisms.

point source - occur at discrete and identifiable points, usually through pipeline discharges or direct dumping including discharges from **sewage** treatment plants, industrial discharges and combined sewer overflows.

population - number of organisms of the same **species** living in a specific area.

pollution - the act or process of polluting or the state of being polluted, especially the contamination of soil, water, or the atmosphere by the discharge of harmful substances; something that pollutes; a pollutant or a group of pollutants.

productivity - the rate of conversion of sunlight and materials by plants into chemical bound energy and materials (photosynthesis).

relative humidity - the amount of moisture in a given amount of air divided by the amount the air could hold at that temperature, expressed as a percentage.

rocky shores - areas of high energy along the coast which are dominated by exposed rock surfaces, attached organisms (brown and green algae) and invertebrates capable of absorbing high energy wave action (blue mussels, barnacles, snails).

run-off - to flow off; drain away; materials carried by rainfall and other water which flows off streets, lawns and other upland areas into bodies of water.

salinity - of, relating to, or containing salt; salty; measured in parts per thousand (ppt) and denoted by a fraction 0/00.

salt marshes- low coastal grassland frequently overflowed by the **tide**; dominated by grasses (Spartina's and Distichlis).

sediments - material that settles to the bottom of a liquid; solid fragments of inorganic or organic material that come from the weathering of rock and are carried and deposited by wind, water, or ice.

septic systems - a commonly used series of buried pipes and tanks which carry human and other wastes from a home, allow for settling of solids (septic tank) and natural removal of **pathogenic bacteria** from the waste water - **septic systems** are on-site waste water treatment systems often implicated in coastal water contamination due to failure of the system or because **nutrients** (nitrogen) are not removed from the waste stream by **septic systems** and therefore reach coastal waters.

sewage - solid and liquid human waste.

shellfish - an aquatic animal, such as a mollusk or crustacean, that has a shell or shell-like exoskeleton.

soundings - a probe of the environment for scientific observation; a measured depth of water; water shallow enough for depth measurements to be taken by a hand line.

species - a group of organisms with a high degree of similarity and which can reproduce and have fertile offspring.

TCE - trichloroethylene - organic compound; known carcinogen, used as a cleaning agent until banned.

tide - periodic variation in the surface level of the oceans and of bays, gulfs, inlets, and estuaries, caused by gravitational attraction of the moon and sun; something that fluctuates like the waters of the **tide**.

tidal current - the motion of water due to the changes, ebbing or flowing of **tides**; especially in estuaries and other coastal water bodies.

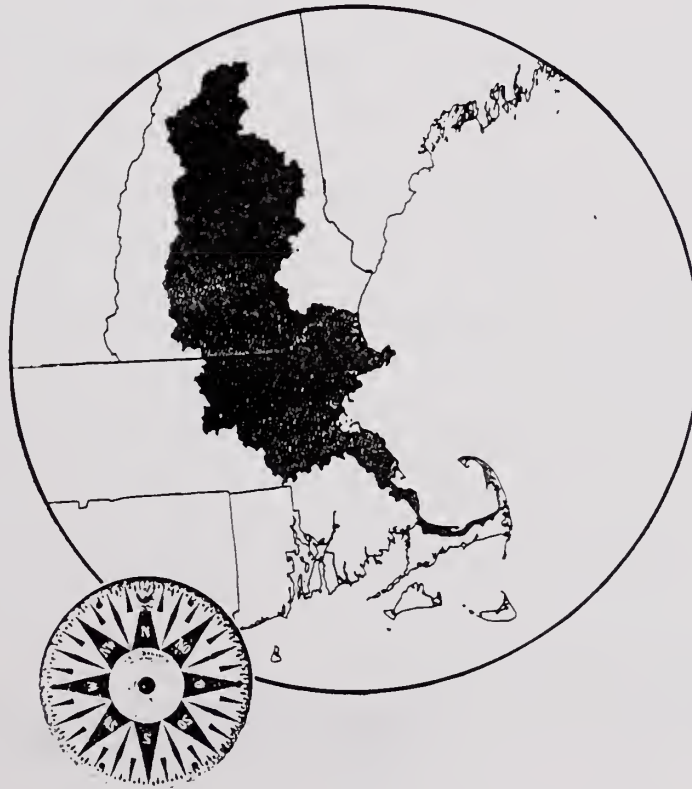
toxin - a chemical, physical or biological agent that causes disease or some change in the normal structure or function of an organism; can be slight or severe in its impact.

tropic level - describes the position of the organism in the food chain.

turbidity - having sediment or foreign particles stirred up or suspended; muddy.

watershed - land area drained by a specific stream or river.

wetlands - land areas along salt or fresh water that are flooded all or part of the time



DATA SHEET - BIOTIC

Plankton - species
Crabs - species
Fish - species
Other Animals - species

Key

Latitude/Longitude - from charts	Salinity - in parts per thousand (ppt)
Dissolved Oxygen - parts/million (ppm) or mg/l	Depth - in meters per sample taken
Temperature - degrees Celsius at depth	

DATA SHEET - ABIOTIC

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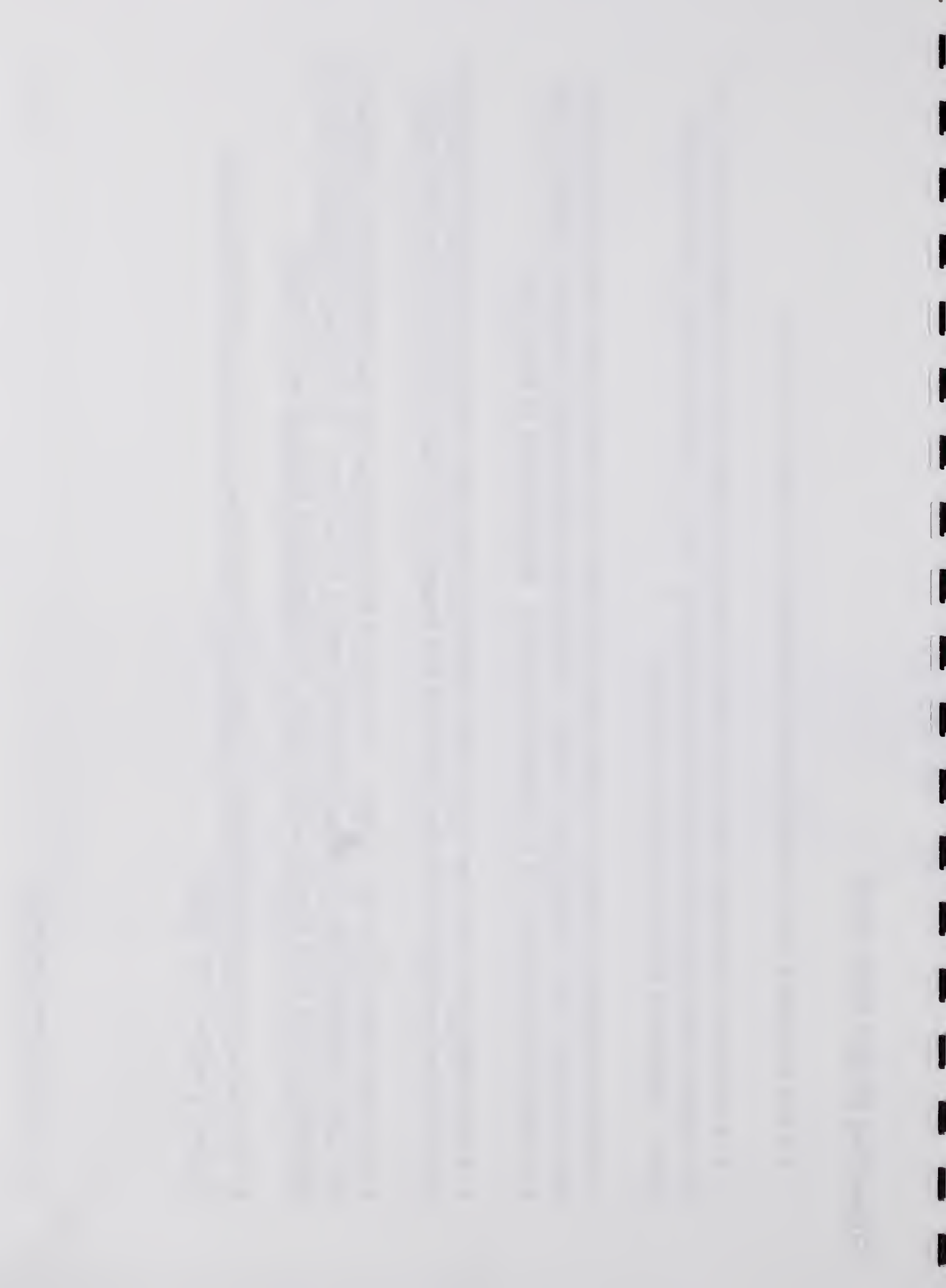
Key

Latitude/Longitude	- from charts	Current velocity	- speed of water passing ship	Salinity	- in parts per thousand (ppt)
Heading	- compass direction of ship	Dissolved Oxygen	- parts/million (ppm) or mg/l	SECCHI	- depth of disappearance
Ship velocity	- ship's apparent speed	Temperature	- degrees Celsius at depth	Color	- from Forel Ule scale
		pH	- on a scale of 1 - 14	Depth	- in meters per sample taken



Collecting Bottle Task Card

1. Tie the weighted line (unweighted end) securely to a cleat on the boat.
2. The bottle will have both ends open and will require these ends to be latched so they do not close on the way to the depth for the sampling. Pull on each end cap until it latches open. Attach the bottle securely to the line.
3. With one student holding the bottle away from the hull, carefully lower the bottle and line into the water never letting go of the line. Watch the graduations on the line until the depth from which the sample is to be taken is reached. Stop the line at this point.
4. After making sure the line is securely attached at the point where you stopped its descent, attach the messenger to the line and drop the messenger down the line to close the bottle.
5. Haul the bottle up to the surface. The top of the bottle can be opened to pour a sample of the water collected into a container for the testing to be done. Do not test samples within the collecting bottle itself except when testing for dissolved oxygen with a meter.
6. The same procedure should be repeated as many times as is needed for the tasks requiring water from depth.



Density (Hydrometer) Task Card

1. Each student should take a turn collecting a sample, testing the sample for density with the hydrometer, measuring the sample's temperature and recording the data. Follow the instructions for use of a collecting bottle (see Water Samples from the Deep). Different bottles have different ways for closing when the depth you want to sample is reached. At least three samples should be taken; one each at the surface, at midwater and near the bottom.
2. Carefully remove the hydrometer from its storage sleeve and gently placed it on the bottom of the clear narrow container. For this task we will use a graduated cylinder made out of plastic. Carefully pour the water sample into the cylinder until the hydrometer floats freely. Hydrometers come with stems which are marked with densities.
3. Carefully read the density from the scale - it will be a number slightly above 1 (one) and will have decimal points to note.
4. Record the density of the water, the depth from which it was taken and any other pertinent observations (location for instance) on the data sheet. Each student should perform this task for one depth.

Table 1
Temperature Correction Table

Measured density	Measured Water Temperature °C																Density of Water at 15 °C				
	0°	1°	2°	3°	4°	5°	6-10°	11°	12°	13-17°	18°	19-21°	22°	23°	24°	25°	26°	27°	28°	29°	30°
1.000	1.000	1.000	.999	.999	.999	.999	.999	1.000	1.000	1.000	1.000	1.001	1.001	1.001	1.002	1.002	1.002	1.002	1.003	1.003	1.003
1.001	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.001	1.001	1.001	1.001	1.002	1.002	1.002	1.003	1.003	1.003	1.003	1.004	1.004	1.004
1.002	1.002	1.001	1.001	1.001	1.001	1.001	1.001	1.002	1.002	1.002	1.003	1.004	1.004	1.004	1.005	1.005	1.005	1.005	1.006	1.006	1.005
1.003	1.002	1.002	1.002	1.002	1.002	1.003	1.003	1.003	1.004	1.004	1.005	1.006	1.006	1.006	1.007	1.007	1.007	1.007	1.008	1.008	1.006
1.004	1.003	1.003	1.003	1.003	1.003	1.003	1.004	1.004	1.005	1.005	1.006	1.007	1.007	1.007	1.008	1.008	1.008	1.008	1.009	1.009	1.007
1.005	1.004	1.004	1.004	1.004	1.004	1.004	1.005	1.005	1.006	1.006	1.007	1.008	1.008	1.008	1.009	1.009	1.009	1.009	1.010	1.010	1.008
1.006	1.005	1.005	1.005	1.005	1.005	1.005	1.006	1.006	1.007	1.007	1.008	1.009	1.009	1.009	1.010	1.010	1.010	1.010	1.011	1.011	1.009
1.007	1.006	1.006	1.006	1.006	1.006	1.006	1.007	1.007	1.008	1.008	1.009	1.010	1.010	1.010	1.011	1.011	1.011	1.011	1.012	1.012	1.010
1.008	1.007	1.007	1.007	1.007	1.007	1.007	1.008	1.008	1.009	1.009	1.010	1.011	1.011	1.011	1.012	1.012	1.012	1.012	1.013	1.013	1.011
1.009	1.008	1.008	1.008	1.008	1.008	1.008	1.009	1.009	1.010	1.010	1.011	1.012	1.012	1.012	1.013	1.013	1.013	1.013	1.014	1.014	1.012
1.010	1.009	1.009	1.009	1.009	1.009	1.009	1.010	1.010	1.011	1.011	1.012	1.013	1.013	1.013	1.014	1.014	1.014	1.014	1.015	1.015	1.013
1.011	1.010	1.010	1.010	1.010	1.010	1.010	1.011	1.011	1.012	1.012	1.013	1.014	1.014	1.014	1.015	1.015	1.015	1.015	1.016	1.016	1.014
1.012	1.011	1.011	1.011	1.011	1.011	1.011	1.012	1.012	1.013	1.013	1.014	1.015	1.015	1.015	1.016	1.016	1.016	1.016	1.017	1.017	1.015
1.013	1.012	1.012	1.012	1.012	1.012	1.012	1.013	1.013	1.014	1.014	1.015	1.016	1.016	1.016	1.017	1.017	1.017	1.017	1.018	1.018	1.016
1.014	1.013	1.013	1.013	1.013	1.013	1.013	1.014	1.014	1.015	1.015	1.016	1.017	1.017	1.017	1.018	1.018	1.018	1.018	1.019	1.019	1.017
1.015	1.014	1.014	1.014	1.014	1.014	1.014	1.015	1.015	1.016	1.016	1.017	1.018	1.018	1.018	1.019	1.019	1.019	1.019	1.020	1.020	1.018
1.016	1.015	1.015	1.015	1.015	1.015	1.015	1.016	1.016	1.017	1.017	1.018	1.019	1.019	1.019	1.020	1.020	1.020	1.020	1.021	1.021	1.019
1.017	1.016	1.016	1.016	1.016	1.016	1.016	1.017	1.017	1.018	1.018	1.019	1.020	1.020	1.020	1.021	1.021	1.021	1.021	1.022	1.022	1.020
1.018	1.017	1.017	1.017	1.017	1.017	1.017	1.018	1.018	1.019	1.019	1.020	1.021	1.021	1.021	1.022	1.022	1.022	1.022	1.023	1.023	1.021
1.019	1.018	1.018	1.018	1.018	1.018	1.018	1.019	1.019	1.020	1.020	1.021	1.022	1.022	1.022	1.023	1.023	1.023	1.023	1.024	1.024	1.022
1.020	1.019	1.019	1.019	1.019	1.019	1.019	1.020	1.020	1.021	1.021	1.022	1.023	1.023	1.023	1.024	1.024	1.024	1.024	1.025	1.025	1.023
1.021	1.020	1.020	1.020	1.020	1.020	1.020	1.021	1.021	1.022	1.022	1.023	1.024	1.024	1.024	1.025	1.025	1.025	1.025	1.026	1.026	1.024
1.022	1.021	1.021	1.021	1.021	1.021	1.021	1.022	1.022	1.023	1.023	1.024	1.025	1.025	1.025	1.026	1.026	1.026	1.026	1.027	1.027	1.025
1.023	1.021	1.021	1.021	1.021	1.021	1.021	1.022	1.022	1.023	1.023	1.024	1.025	1.025	1.025	1.026	1.026	1.026	1.026	1.027	1.027	1.026
1.024	1.022	1.022	1.022	1.022	1.022	1.022	1.023	1.023	1.024	1.024	1.025	1.026	1.026	1.026	1.027	1.027	1.027	1.027	1.028	1.028	1.027
1.025	1.023	1.023	1.023	1.023	1.023	1.023	1.024	1.024	1.025	1.025	1.026	1.027	1.027	1.027	1.028	1.028	1.028	1.028	1.029	1.029	1.028
1.026	1.024	1.024	1.024	1.024	1.024	1.024	1.025	1.025	1.026	1.026	1.027	1.028	1.028	1.028	1.029	1.029	1.029	1.029	1.030	1.030	1.029
1.027	1.025	1.025	1.025	1.025	1.025	1.025	1.026	1.026	1.027	1.027	1.028	1.029	1.029	1.029	1.030	1.030	1.030	1.030	1.031	1.031	1.030
1.028	1.026	1.026	1.026	1.026	1.026	1.026	1.027	1.027	1.028	1.028	1.029	1.030	1.030	1.030	1.031	1.031	1.031	1.031	1.032	1.032	1.031
1.029	1.027	1.027	1.027	1.027	1.027	1.027	1.028	1.028	1.029	1.029	1.030	1.031	1.031	1.031	1.032	1.032	1.032	1.032	1.033	1.033	1.032
1.030	1.028	1.028	1.028	1.028	1.028	1.028	1.029	1.029	1.030	1.030	1.031	1.032	1.032	1.032	1.033	1.033	1.033	1.033	1.034	1.034	1.033
1.031	1.029	1.029	1.029	1.029	1.029	1.029	1.030	1.030	1.031	1.031	1.032	1.032	1.032	1.033	1.033	1.034	1.034	1.034	1.035	1.035	1.034

Note. This table provides the temperature corrected densities at 15 °C of water temperature, not changes in your hydrometer calibration. Therefore, for more accurate results you should adjust the water temperature of your sample to 15 °C before making a hydrometer reading rather than use this table

This table only takes into account changes in water density due to

Salinity (Refractometer) Task Card

1. Using a navigation chart determine the location of the ship relative to the shore, rivers nearby and the open ocean.
2. Using a collecting bottle, collect a sample at the depth and location desired.
3. Refractometers have a flap of plastic over a glass surface. With a pipette or eyedropper, rinse the glass surface twice with distilled water.
4. With a pipette or eyedropper, drop 2 - 3 drops of sample water onto the glass surface making sure the area is covered. Close the flap making sure to remove any air bubbles and to ensure the glass surface is covered completely.
5. Hold the refractometer horizontally and bring it up to your eye. Look through the eyepiece, making sure that light can enter the other end without obstruction.
6. Peer into the eyepiece and note the location where the blue area ends and the clear or white area begins. This line corresponds to marks in the refractometer for percentage **salinity**.
7. Note the level of **salinity** and mark it down on the data sheet.
8. Thoroughly rinse off the glass surface and cover flap with distilled water, air dry both areas and return the refractometer to its case.

Dissolved oxygen Task Card

1. Using a navigation chart determine the location of the ship relative to the shore, to rivers nearby, to the open ocean and to heavy development by people on shore.
2. Using a collecting bottle, collect a sample at the depth and location desired.
3. Do not pour the sample collected into a separate container. Immediately upon bringing the sample to the surface, open the collecting bottle without agitating it, place the probe in the sample and read the dissolved oxygen level from the meter. Record this data.
4. Repeat the procedure for different depths (surface, mid-water, bottom).

Fertilizer and Limits to Growth (Nutrients) Task Card

1. Using a navigation chart determine the location of the ship relative to the shore, or rivers nearby, to the open ocean and to heavy development by people on shore.
2. Using a collecting bottle, collect a sample at the depth and location desired.
3. Pour the sample collected into a separate container. From this container you can take samples which can be tested using the nitrate testing kit. After adding a reagent, the color of the sample is compared to the colors provided with the kit. Record the reading.
4. Repeat the procedure for different depths (surface, mid-water, bottom).
5. Dispose of the water and reagent in a waste water container.

Temperature Task Card

1. Using a water collecting bottle, collect a sample at the surface of water and immediately test this sample for temperature by placing the thermometer directly into the sampling bottle and recording the temperature. This test and dissolved oxygen are the only exceptions to not using the collecting bottle for testing the sample.
2. Repeat the same procedure for at least two locations. One location should be close to the bottom of the water where the samples are being taken and a third midwater.
3. Repeat the above at other depths as time allows.
4. Record the temperatures and depths.

Color in Water (Forel Ule) Task Card

1. Each student should take a turn collecting a sample, testing the sample for color with the Forel Ule Scale, and recording the data. Follow the instructions for use of a collecting bottle. Different bottles have different ways for closing when the depth you want to sample is reached. At least three samples should be taken; one each at the surface, at midwater and near the bottom.
2. Pour a sample of the water into the glass tube which accompanies the scale. Compare the sample taken to the scale and record the data.
3. Repeat at three depths or different locations.
4. Record the color found.

SECCHI Disk Task Card

1. Tie the line securely at the end of the SECCHI disk to a cleat or other part of the ship. With one student holding the disk away from the hull, carefully lower the disk into the water never letting go of the line.
2. The second student should watch the disk and when the disk can no longer be seen the line should stop being played out.
3. The marker on the line should be noted and the amount of line length underwater called out to the third student for recording.
4. The same procedure should be repeated three times with each student taking turns to read the length of line and playing the line out over the side.
5. Record the depth where the disk disappears.

Ocean's Bottom - Exploring the Benthos Task Card

1. Using a navigation chart determine the location of the ship and the type of bottom where the sampling will take place. Determine the location of the ship relative to the shore, to rivers nearby and to the open ocean. Using the fathometer, determine the depth in the area. A soft bottom is needed for this activity. Rocky bottoms may snag or damage the samplers and will produce little if any results.
2. The bottom grab is hinged and a latch is provided which prevents closure until the grab hits bottom. If a corer is being used this will have a safety catch on it which needs to be set in advance of lowering it over the side. Make sure lines holding the grab or corer are securely attached.
3. Securely attach the loose end of the line to a cleat or other point on the ship. If a block and tackle is available run the line through first and then attach to a cleat. Lower the grab or corer over the side **VERY CAREFULLY**. Allow the grab or corer to freely drop to the bottom. Note the depth from the line attached.
4. Pull the grab or corer from the bottom. This may take several people as the sampler will be filled with sediments and water. Carefully hoist the grab or corer over the side.
5. If time allows, resample at different locations.
6. Open the grab into a very large bucket or tray (a wooden tray can be made to prevent damage to the deck but the one short side should be hinged to allow for rinsing the sediments back to the sea. Be careful with fingers as the grab is opened. Open the corer and using a pole or plunger push the core out into a tray or the deck.
7. Observe the sediments. Note smell, color, zonation (with the corer), location of animals or plants, texture (rub some of the sediments through fingers) and size of particles. Pass a sample of the sediments through a sieve set to determine grain size. Coarse grains allow for greater passage of materials and animals through the sediments while finer grains are denser, heavier and can hold higher concentrations of contaminants such as heavy metals.
8. Using field guides, identify the species of animals collected and the number of each species. Record this information.
9. Clean the grab or corer with sea water and rinse the animals back into the water with the sediments.

Currents and Velocity Task Card

1. Measure a distance, such as 60 feet, as a start and stop point for release and retrieval of the drogue or float. This distance is approximately 1/100 if a nautical mile (6080 feet to a nautical mile; 1 nautical mile per hour = 1 knot).
2. One student releases the drogue or float at a point beyond or before the starting point for timing. This The drogue or float hits the water, floats to the surface and begins moving at a constant speed, prior to sampling. As the drogue or float passes the starting point the water, start the stopwatch and begin timing. The line, attached to the drogue must play out freely, if a line is used.
3. When the stop point is reached the third student calls out and the stop watch and timing are stopped. Immediately retrieve the drogue or float with the gaff. The line attached should be used as a safety so that the drogue or float is not lost.
4. Record the time and rotate from position to position so each student takes a turn taking measurements and recording the estimated rate of **current** or velocity.

Plankton Task Card

1. Construct the net assembly with catch bucket, net, open ring bridle and tow line securely attached together.
2. Secure the line of the net to a cleat in the rear quarter or stern of the boat.
3. Slowly lower the net into the water and let the line play out unimpeded, but maintain a light tension on the line to keep the net floating in sight and close to the surface. Let all the line play out and beginning timing the length of the sampling. Note the speed at which the boat is moving.
4. After 5 -10 minutes (more on longer expeditions), haul the assembly back to the boat (note the end time of the sampling) making sure that the catch bucket is the hanging down allowing water to flow through and around it but not letting the sample spill out. Pour the contents of the catch bucket into a sample bottle.
5. Below decks, use an eyedropper or pipette to extract a sample of the **plankton** captured. Examine under a microscope to determine number and kinds of **plankton** discovered. Move rapidly because **plankton** do not live long through the changes in oxygen levels and temperature which go with being under a microscope.
6. Using keys and guides, identify as many **plankton** as time allows. Record your findings.

Pathogens Task Card

1. Using a navigation chart determine the location of the ship relative to the shore, to rivers nearby, to the open ocean and to heavy development by people on shore.
2. Using a collecting bottle, collect a sample at the depth and location desired.
3. Label a sterilized sample bag. Pour at least 100 ml of the sample collected into the bag and seal immediately. Place the sample in the cooler and add an ice pack.
4. Repeat the procedure for different locations on the voyage.
5. Take the sample either to an on board lab or back to the classroom (in this case the cooler and ice pack should come from the school). Follow the directions on the Millipore kit for membrane filtering, for preparation of the sample for incubation in the small petri disc provided and for incubation itself. Usually 24 -48 hours at 35 degrees Celsius will allow for bacterial growth and then for analysis of results.
6. Dispose of the incubated sample by plunging in chlorine bleach.

Macroalgae Task Card

1. Construct the net assembly with catch bucket, net, open ring bridle and tow line securely attached together.
2. Secure the line of the net to a cleat in the rear quarter or stern of the boat.
3. Slowly lower the net into the water and let the line play out unimpeded, but maintain a light tension on the line to keep the net floating in sight and at the surface.
4. Let all the line play out and beginning timing the length of the sampling. Note the speed at which the boat is moving.
5. After 5 -10 minutes (more on longer expeditions), haul the assembly back to the boat making sure that the catch bucket is the hanging down allowing water to flow through and around it but not letting the sample spill out. If you have traveled through a large mat of algae this procedure may take only a minute or two to fill the net.
6. Pour the contents of the net into an examination tray or bucket.
7. Examine samples of the algae and use a field guide to determine the type of algae caught. Under a dissecting microscope or with a hand lens to determine number and kinds of organisms discovered.
8. Using keys and guides, identify as many organisms as time allows.

(Optional - Save a sample of the algae for later study by preserving with a plant press. A plant press can be constructed out of 2 12"x12" pieces of plywood between which are stacked layers of newspaper and around which straps are placed to tighten the press. Label the paper first with pencil. Place the algae carefully on specimen paper by floating the algae in the examination tray and sliding the paper under the specimen. Spread out the sample, cover with newspaper and place in the press. Replace the newspaper every day until the algae is completely dry. Preserve by covering with a large, clear plastic bag or clear plastic wrap.)

Minnow Trap Task Card

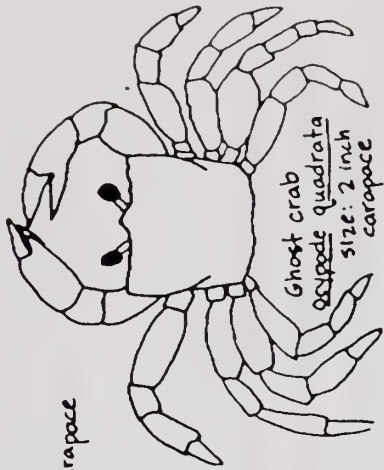
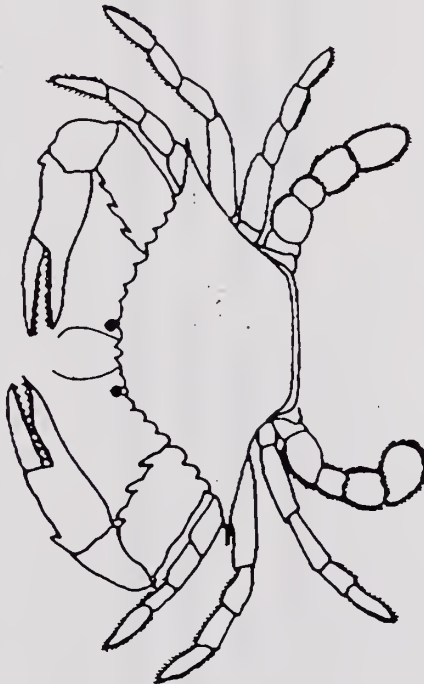
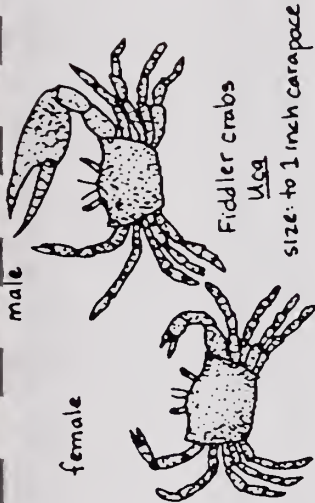
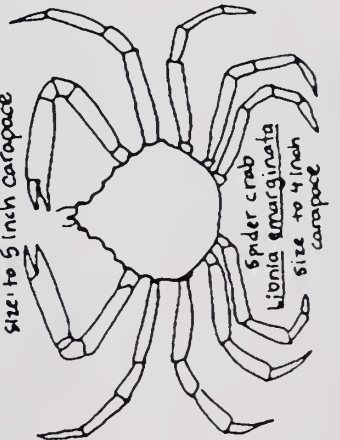
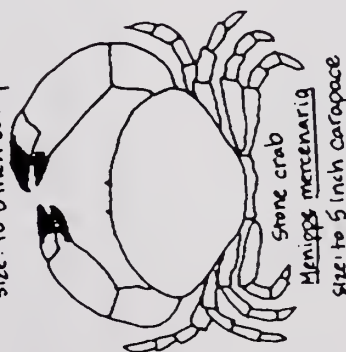
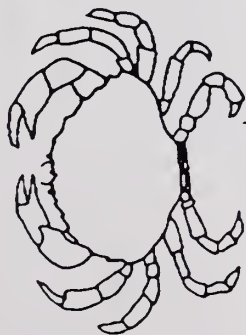
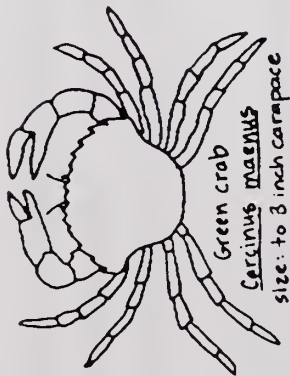
1. Using a navigation chart determine the location of the ship and the type of bottom where the sampling will take place. Determine the location of the ship relative to the shore, to rivers nearby and to the open ocean. Using the fathometer, determine the depth in the area.
2. The minnow trap is in two parts and has a line attached to it. Place bait in one half of the trap and connect the two halves together. Make sure the line is securely attached to the trap.
3. Securely attach the loose end of the line to a cleat or other point on the ship. Slowly lower the minnow trap to the depth you wish to sample. Record the depth at which the sampling will take place and the time when the sampling began.
4. After as long a time as possible, but not to exceed 8 hours, pull the trap from the water and open the trap over a bucket or portable fish tank. The water in the bucket should be taken from the location and depth (if possible with the collecting bottle) at which the trap was left for sampling.
5. If time and traps allow, resample at different depths with separate traps. Simultaneous sampling at different depths is desirable.
6. Using field guides, identify the species of animals collected and the number of each species. Record this information.

Crab Trap Task Card

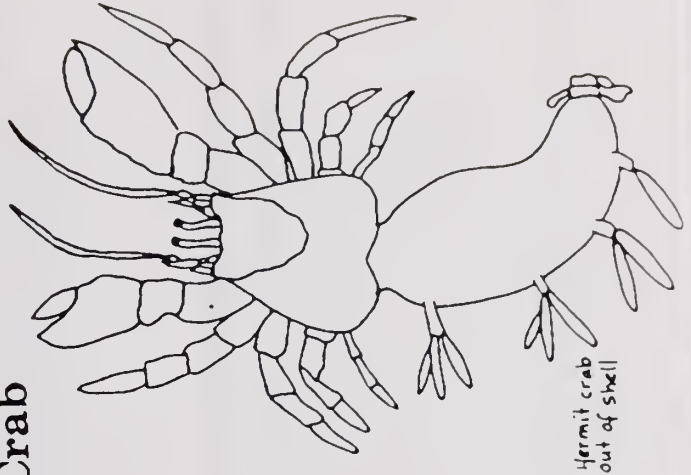
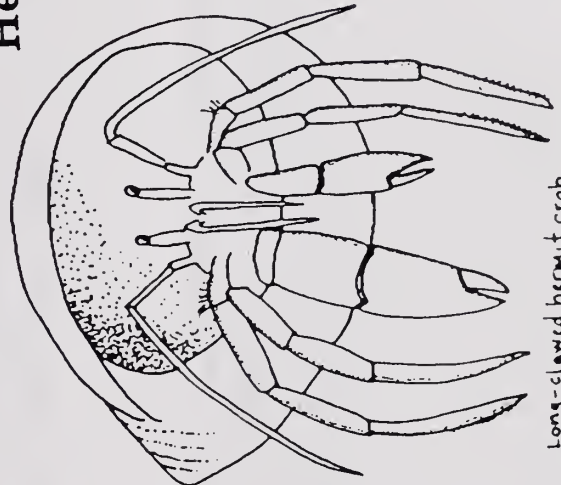
1. Using a navigation chart determine the location of the ship and the type of bottom where the sampling will take place. Determine the location of the ship relative to the shore, to rivers nearby and to the open ocean. Using the fathometer, determine the depth in the area.
2. The crab trap is simple to use. A line is attached to the trap allowing you to lower it to the bottom (or to any depth - with crab traps you want to bait and fish the bottom. Place bait in the center of the trap. Make sure the line is securely attached to the trap.
3. Securely attach the loose end of the line to a cleat or other point on the ship. Slowly lower the trap to the bottom where you wish to sample. Record the depth at which the sampling will take place and the time when the sampling began.
4. After as long a time as possible, but not to exceed 8 hours, pull the trap from the water. Remove each crab and place it in a bucket or portable fish tank. The water in the bucket should be taken from the location and depth (if possible with the collecting bottle) at which the trap was left for sampling.
5. If time and traps allow, resample at different locations with separate traps. Simultaneous sampling at different areas is desirable.
6. Using field guides, identify the species of animals collected and the number of each species. Record this information.



Crabs



Hermit Crab



Marine Mammals Task Card

1. The team of two students should review the card of marine mammals likely to be seen on or under the water. Don't expect to memorize from the card, only get an idea of general body shape, colors and size.
 2. Stand amidships and one student should scan the waters from the bow to the stern as far as can be clearly seen for identification purposes. As a marine mammals is sighted a record should be made of what was seen. The second should keep records and assist by finding species in the field guide or identification cards. Students should take turns doing the scanning and the recording.
 3. As time allows, watch individual marine mammals to determine what behaviors they are demonstrating. Included in behaviors are resting, diving, rapid swimming, lob tailing, flipper flapping, hauling out, spy hopping or watching, feeding, or other behaviors which are observable.
- (Optional - Pull a neuston or plankton tow through an area where whales have been feeding to determine what they might be using for food in this area. Make sure to do this after the whales have left: otherwise you would be breaking the law!)



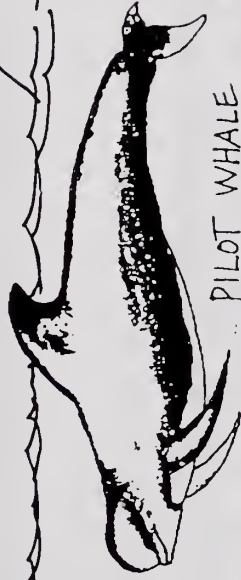
Marine Mammals



HARBOR SEAL



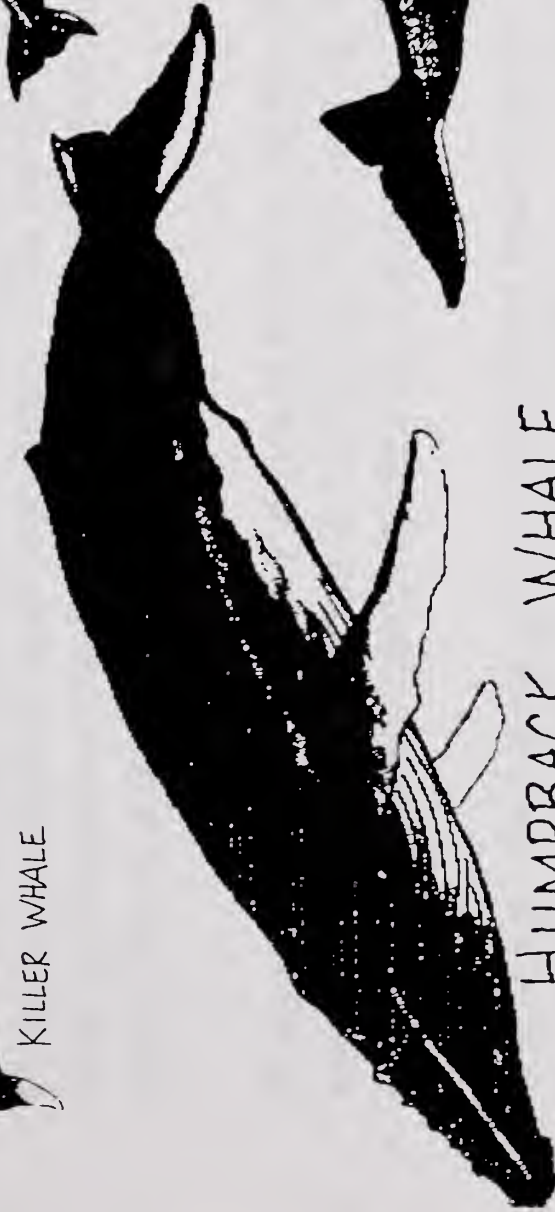
KILLER WHALE



PILOT WHALE



MINKE WHALE



HUMPBACK WHALE



RIGHT WHALE



FIN WHALE

Over and Under the Waters - Birds Task Card

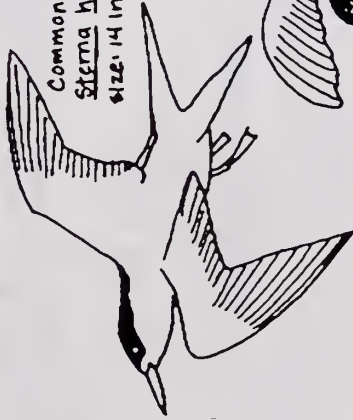
1. The team of two students should review the card of birds likely to be seen on or near the water. Don't expect to memorize from the card, only get an idea of general body shape and size.
2. Stand amidships and one student should scan the waters from the bow to the stern as far as can be clearly seen for identification purposes. As a bird is sighted a record should be made of what was seen. The second should keep records and assist by finding species in the field guide or identification cards. Students should take turns doing the scanning and the recording.
3. As time allows, watch individual birds to determine what behaviors they are demonstrating. Included in behaviors are resting, soaring, flap flying, feeding, diving, tipping up to feed, carrying nesting materials or other behaviors which are observable.

(Optional - Pull a neuston or plankton tow through an area where birds have been feeding to determine what they might be using for food in this area.)

Shoreline Survey Task Card

1. Lay out a navigational chart of the area from which the ship will sail (harbor, for example).
2. Take a blank transparency and a sharp pointed dry erase marker and trace the shoreline.
3. Locate a starting point (landmark, building, geologic feature) on the navigational chart and on the traced transparency. This point is the start for the survey.
4. With the naked eye or binoculars, examine the shoreline and mark on the transparency for each of the uses.
5. Create a code (such as a letter or number for each use - repeating the letter or number along the shore if the area covered by that use is larger than a single number or letter)
6. Among the uses of the shoreline are the following categories:
 - open, natural (woods, marshes, beaches, rocky shores)
 - open, disturbed space (city lots, abandoned land)
 - single family housing including beach homes
 - multiple family housing (apartment buildings, large and small) office buildings marinas and boat yards
 - docks, piers
 - industrial buildings
 - museums
 - amusement parks, aquaria or other recreation
 - waste water (pollution) treatment plants
 - farms
 - roads
 - other (specify)

Gulls, Terns, and Skimmers



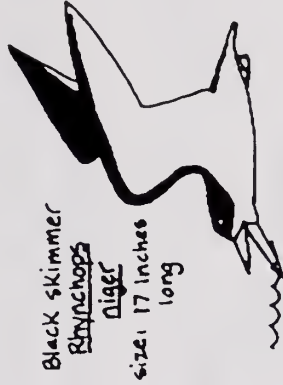
Common tern
Sterna hirundo
size: 14 inches long



Laughing gull
Larus stricilla
size: 13 inches long



Herring gull
Larus argentatus
size: 20 inches long



Black skimmer
Rhyncobops niger
size: 17 inches long

Shorebirds

Least sandpiper
Calidris minutilla
size: 5 inches long



Greater yellowlegs
Tringa melanoleuca
size: 11 inches long



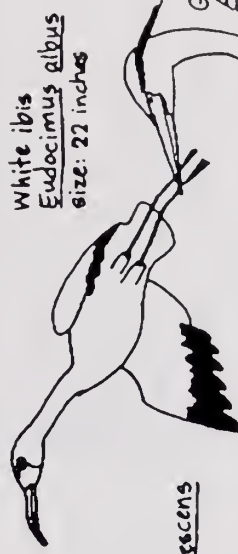
American oystercatcher
Haematopus palliatus
size: 16 inches long



Ruddy turnstone
Arenaria interpres
size: 7 inches long

Egrets, Herons, and Ibis

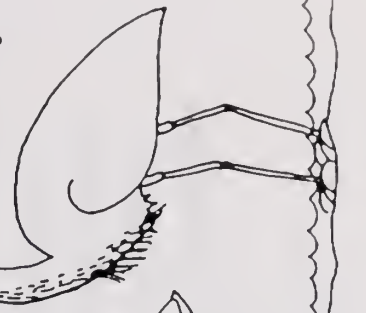
White ibis
Eudocimus albus
size: 22 inches



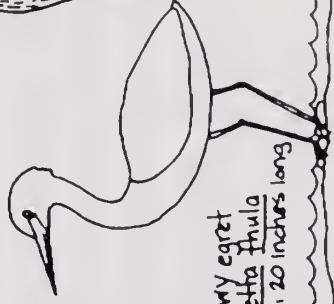
Reddish egret
Dichromiastrea rufescens
size: 25 inches long

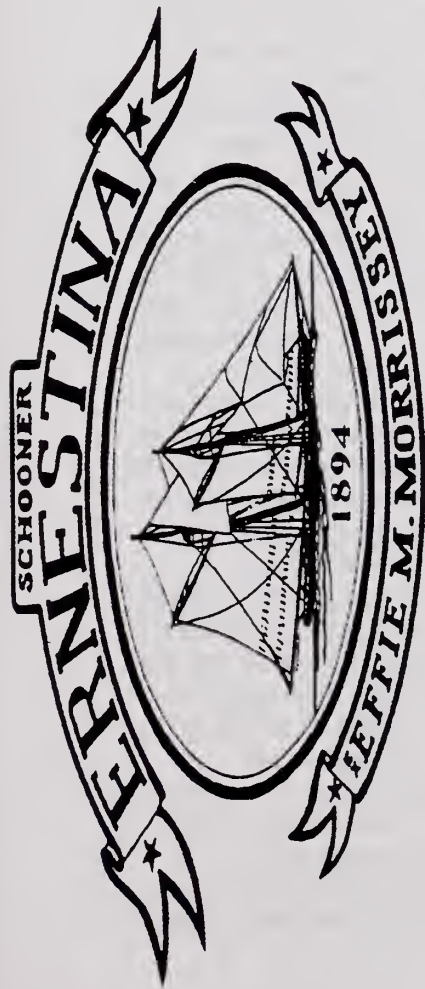


Great blue heron
Ardea herodias
size: 40 inches long



Snowy egret
Egretta thula
size: 20 inches long





More than one hundred years old, the Schooner Ernestina now sails as a school ship for the Commonwealth of Massachusetts' Department of Environmental Management. A living museum and cultural ambassador, Ernestina continues to make history through educational programs celebrating human diversity and creativity.

HISTORY

- 1894 Schooner Effie M. Morrissey is built in Essex, MA.
- 1904 Morrissey begins fishing out of Digby, Nova Scotia.
- 1914 Morrissey serves as a coastal packet along the coasts of Nova Scotia, Newfoundland, and Labrador.
- 1926 Morrissey, under the command of Captain. Bob Bartlett, sets off on the first of twenty Arctic exploration voyages. She sails within 600 miles of the north pole.
- 1941 Morrissey serves as a U.S. Navy survey and supply ship in the Arctic.
- 1948 Captain. Henrique Mendes renames the schooner *Ernestina*, and the ship begins 25 years in Cape Verde packet trade.
- 1982 *Ernestina* sails once again to New England, a gift from the Republic of Cape Verde to the people of the United States.
- 1986 *Ernestina* begins her fourth life as a Sailing School Vessel, after becoming a National Historic Landmark.

STATISTICS

Length Overall: 156 ft.	Designer: George M. McClain
Length at Waterline: 93 ft.	Builder: James & Tarr Shipyard
Beam: 24ft. 5 in.	Gross Tonnage: 98 tons
Draft: 13 ft.	Displacement: 240 tons
Onboard Educational Staff: 12	
Social & Civic Events: up to 80 people	
Educational Day Programs: up to 65 people	
Overnight Programs: up to 24 people	
U. S. Coast Guard Certificate: Subchapters T & R	

Of some seven thousand fishing schooners built in Essex, the Ernestina sails proudly as one of six surviving vessels. She now serves communities from Mt. Hope Bay to Cape Ann.

An Expedition of Discovery ~ Seven Decades Ago!

An account of the activities of Schooner ERNESTINA (then EFFIE M. MORRISSEY) during the first two of twenty voyages of discovery under the command of Captain Robert "Bob" Bartlett. Excerpted from "The Many Lives of the ERNESTINA MORRISSEY" by Michael Platzer.

After the First World War, Robert Bartlett, who had been Admiral Peary's right hand man for the polar expeditions, was without a job. He had an idea for a full-fledged Arctic expedition involving a drift across the Arctic Sea. Over dinner at the New York Yacht Club, he approached James B. Ford, the Vice President of U.S. Rubber Co., regarding sponsorship of the venture and the acquisition of a vessel. Commodore Ford was hesitant and consulted with Isaiah Bowman of the American Geographical Society. Bowman counseled against attempting a multi-year Arctic drift project, but suggested taking scientific parties north on a seasonal basis to conduct research and collect marine and land specimens. At this point Commodore Ford underwrote the purchase of the EFFIE M. MORRISSEY for the price of \$6,000.

Bartlett still needed a sponsor for the expedition. He had been invited to the home of George Palmer Putnam, the publisher, in Rye, New York. As they walked across the snow-covered Apawamis golf links, Bartlett talked of the wondrous sights of North Greenland, of how puny were the Westchester snowstorms compared to the Arctic variety. Along about the eleventh green, which was deeply drifted over, Putnam began to imagine himself in the land of walrus and glacier: he agreed then and there to help Bartlett with a trip the following summer.

An expedition was planned that included an agreement with the American Museum of Natural History for the collection of specimens for exhibition in the new Hall of Ocean Life. Also, a group from the University of Michigan, under Professor William H. Hobbs, would join the trip in order to study the ice cap and its effect on global weather systems.

The MORRISSEY was brought to New York and refitted at McWilliams' shipyard on Staten Island, made possible by a contribution from the financier, Harrison Williams. To take the punishment of ice, her prow and forward hull was sheathed with greenheart from Central America. A Diesel engine and radio were installed and the midships hold, where cod once was stored, was made a messroom and lined with bunks. A power winch on deck replaced the old hand capstan and a toilet was installed. Bartlett described all this as "...nothing fancy or extravagant. Just a good sensible seamanlike outfit, not for looks or comfort, but for service."

They left New York from Rye in mid-June, 1926, and covered 8,500 miles in that long summer. Bartlett admits, "I suppose we drove her a bit. Anyway, it's not hard to cover a lot of ground when you have twenty-four hours of daylight. And on top of that, we struck a grand summer - about the best weather that there has been in North Greenland perhaps for fifty years. Thanks to the amazing ice conditions, we hung up a record or two. We crossed Melville Bay three times; which I don't think has ever been done before in a single season." Apparently they also had a close call when the MORRISSEY got stuck on a reef off Northumberland Island; they had unload all their cargo on the beach and finally the high tide got her off. Sailing to Upernivik, she was repaired with the help of the Danish colonial settlement there.

Capt. Bartlett was a close acquaintance of Knud Rasmussen, the great Danish explorer and authority on Eskimos. Bartlett also had many friends among the native population from his days with Admiral Peary. He was very sensitive to the ecological destruction taking place due to the incursions of the white man and his technology. Dan Streeter, who chronicled the expedition in *Arctic Rodeo*, revealed the deplorable corruption of the Eskimo way of life through the introduction of manufactured goods such as cloth and milled lumber.

Another author on board the MORRISSEY that summer was fourteen-year-old David Binney Putnam, writer of *David Goes to Greenland* (G.P. Putnam's Sons, 1926), a boy's "true life adventure" in the frozen north that would inspire a generation of young readers. During the next twenty years, Captain Bob took over one hundred young men on similar expeditions. As he put it, "...it was good tonic for them to be getting their hands dirty, their muscles hard and their minds cleaned out with the honest experience of the sea and far places."

The expedition captured two polar bears which were delivered to the New York Zoo. Upon completion of the trip, Teddy Roosevelt congratulated Bartlett and the crew for their contribution to the knowledge of the Arctic.

George Palmer Putnam, pleased with the 1926 expedition, organized another for the following year. This time the voyage was under the auspices of the American Geological Society, the Museum of the American Indian, Heye Foundation, the American Museum of Natural History and the Buffalo Society

of Natural Sciences. The primary purpose was the mapping of Baffin Island - the world's fifth largest island - which had not been surveyed since the 1631 expedition of Luke Fox.

Putnam gathered leading scientists including Prof. Lawrence Gould of the University of Michigan, who was in charge of the map-making program. Gould would later go with Admiral Byrd to the Antarctic. Also aboard was Robert E. Peary, son of the famous explorer and George Weymouth of the Carnegie Institute. Leading anthropological activities was Donald Cadzow of the Museum of the American Indian. Dr. Peter Heinbecker, George Washington University, continued his blood grouping and dietetic studies of the Eskimo begun the previous year in North Greenland. Fred Limekiller of the American Museum of Natural History supervised zoological collecting. A special study of the plankton in the Hudson Strait and beyond was conducted for the Buffalo Society of Natural Sciences. For a second year, the MORRISSEY crew included botanist Junius Bird.



illustrations from: "David Goes to Greenland"

written by David Binney Putnam, Morrissey voyage of 1926

